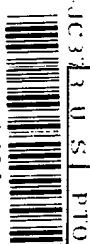


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12/14/98



JCS40 U.S. PTO

DIVISION-CONTINUATION APPLICATION TRANSMITTAL FORM

Attorney Docket No.:

A-451-F

 Anticipated Classification Of This Application:
 Class _____ Subclass _____

 Prior Application:
 Examiner
 Carlson, K.

 Art Unit
 1652

JCS40 U.S. PTO

09/21/97



12/14/98

To the Assistant Commissioner for Patents:

 This is a request for filing a ☒ continuation ☐ divisional application, under 37 CFR 1.53(b), of pending prior application
 Serial No. 08/880,855 filed on June 23 19 97,
of William J. Boylefor OSTEOPROTEGERIN BINDING PROTEINS
 1. ☒ Enclosed is a copy of the prior application, Serial No. 08/880,855, filed on June 23, 1997
 including the oath or declaration as originally filed.

 2. ☒ The filing fee is calculated below:

For	Number Filed		Number Extra		Rate	Fee
Total Claims	41	- 20 =	21	x	\$22.00 =	\$462.00
Independent Claims	11	- 3 =	8	x	\$82.00 =	656.00
Multiple Dependent Claims	5			+	\$270.00 =	270.00
Basic Fee					\$790.00 =	790.00
Total Filing Fee						\$2,178.00

 3. ☒ The Commissioner is hereby authorized to charge any filing fees which may be required by the accompanying application, any additional fees which may be required during pendency of this application, or credit any over-payment to Deposit Account No. 01-0519 in the name of Amgen Inc. An original and one copy are enclosed.

 4. ☐ A check in the amount of \$ _____ is enclosed.

 5. ☐ Cancel in this application original claims _____
 of the prior application before calculating the filing fee. (At least one original independent claim must be retained for filing purposes.)

 6. ☒ Amend the specification by inserting before the first line the sentence:

 --This application is a ☒ continuation ☐ division of application Serial No. 08/880,855,
 filed June 23, 1997, which is a continuation-in-part of application Serial No. 08/842,842, filed April 16, 1997, now U.S.
 Patent No. 5,843,678, which is hereby incorporated by reference.--

EXPRESS MAIL CERTIFICATE

Express Mail mail labeling number

EL19 8793110US

Date of Deposit.

December 14, 1998

I hereby certify that this paper or fee is being deposited with the United States Postal Service *Express Mail Post Office to Addressee* service under 37 CFR 1.10 on the date indicated above and is addressed to Box Patent Application, Assistant Commissioner for Patents, Washington, DC 20231.

Ellen J. Sorensen
 Printed Name

Ellen J. Sorensen
 Signature

7. ☐ Transfer the drawings from the prior application to this application and abandon said prior application as of the filing date accorded this application. A duplicate copy of this sheet is enclosed for filing in the prior application file. (May only be used if signed by person authorized by § 1.138 and before payment of base issue fee.)

7a. ☐ New formal drawings are enclosed.

8. ☐ Priority of application Serial No. _____ filed on _____ in _____ (country) is claimed under 35 USC 119.

8a. ☐ The certified copy has been filed in prior application Serial No. _____ filed _____

9. ☒ The prior application is assigned of record to Amgen Inc.

10. ☐ A preliminary amendment is enclosed.

11. ☐ Also enclosed _____

12. ☐ Other: _____

13. ☒ The power of attorney in the prior application is to:
Ron K. Levy, Registration No. 31,539; Steven M. Odre, Registration No. 29,094;
Robert B. Winter, Registration No. 34,458

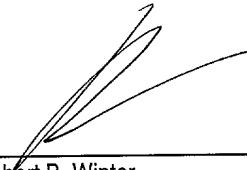
a. ☒ The power appears in the original papers in the prior application.

b. ☐ Since the power does not appear in the original papers, a copy of the power in the prior application is enclosed.

c. ☒ Address all future communications to
Robert B. Winter
 at the address below.

Signator: ☐ Assignee of complete interest

☒ Attorney or agent of record


 Robert B. Winter
 Attorney/Agent for Applicant(s)
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OSTEOPROTEGERIN BINDING PROTEINS

Field of the Invention

5 The present invention relates to polypeptides
which are involved in osteoclast differentiation. More
particularly, the invention relates to osteoprotegerin
binding proteins, nucleic acids encoding the proteins,
expression vectors and host cells for production of the
10 proteins, and binding assays. Compositions and methods
for the treatment of bone diseases, such as
osteoporosis, bone loss from arthritis, Paget's disease,
and hypercalcemia, are also described.

15

Background of the Invention

Living bone tissue exhibits a dynamic
equilibrium between deposition and resorption of bone.
These processes are mediated primarily by two cell
20 types: osteoblasts, which secrete molecules that
comprise the organic matrix of bone; and osteoclasts,
which promote dissolution of the bone matrix and
solubilization of bone salts. In young individuals with
growing bone, the rate of bone deposition exceeds the
25 rate of bone resorption, while in older individuals the
rate of resorption can exceed deposition. In the latter
situation, the increased breakdown of bone leads to
reduced bone mass and strength, increased risk of
fractures, and slow or incomplete repair of broken
30 bones.

Osteoclasts are large phagocytic multinucleated
cells which are formed from hematopoietic precursor
cells in the bone marrow. Although the growth and
formation of mature functional osteoclasts is not well

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understood, it is thought that osteoclasts mature along the monocyte/macrophage cell lineage in response to exposure to various growth-promoting factors. Early development of bone marrow precursor cells to
5 preosteoclasts are believed to mediated by soluble factors such as tumor necrosis factor- α (TNF- α), tumor necrosis factor- β (TNF- β), interleukin-1 (IL-1), interleukin-4 (IL-4), interleukin-6 (IL-6), and leukemia inhibitory factor (LIF). In culture, preosteoclasts are
10 formed in the presence of added macrophage colony stimualting factor (M-CSF). These factors act primarily in early steps of osteoclast development. The involvement of polypeptide factors in terminal stages of osteoclast formation has not been extensively reported.
15 It has been reported, however, that parathyroid hormone stimulates the formation and activity of osteoclasts and that calcitonin has the opposite effect, although to a lesser extent.

Recently, a new polypeptide factor, termed
20 osteoprotegerin (OPG), has been described which negatively regulated formation of osteoclasts in vitro and in vivo (see co-owned and co-pending U.S. Serial Nos. 08/577,788 filed December 22, 1995, 08/706,945 filed September 3, 1996, and 08/771,777, filed December
25 20, 1996, hereby incorporated by reference; and PCT Application No. W096/26271). OPG dramatically increased the bone density in transgenic mice expressing the OPG polypeptide and reduced the extent of bone loss when administered to ovariectomized rats. An analysis of OPG
30 activity in in vitro osteoclast formation revealed that OPG does not interfere with the growth and differentiation of monocyte/macrophage precursors, but more likely blocks the differentiation of osteoclasts from monocyte/macrophage precursors. Thus OPG appears

to have specificity in regulating the extent of osteoclast formation.

OPG comprises two polypeptide domains having different structural and functional properties. The amino-terminal domain spanning about residues 22-194 of the full-length polypeptide (the N-terminal methionine is designated residue 1) shows homology to other members of the tumor necrosis factor receptor (TNFR) family, especially TNFR-2, through conservation of cysteine rich domains characteristic of TNFR family members. The carboxy terminal domain spanning residues 194-401 has no significant homology to any known sequences. Unlike a number of other TNFR family members, OPG appears to be exclusively a secreted protein and does not appear to be synthesized as a membrane associated form.

Based upon its activity as a negative regulator of osteoclast formation, it is postulated that OPG may bind to a polypeptide factor involved in osteoclast differentiation and thereby block one or more terminal steps leading to formation of a mature osteoclast.

It is therefore an object of the invention to identify polypeptides which interact with OPG. Said polypeptides may play a role in osteoclast maturation and may be useful in the treatment of bone diseases.

Summary of the Invention

A novel member of the tumor necrosis factor family has been identified from a murine cDNA library expressed in COS cells screened using a recombinant OPG-Fc fusion protein as an affinity probe. The new polypeptide is a transmembrane OPG binding protein which is predicted to be 316 amino acids in length, and has an amino terminal cytoplasmic domain, a transmembrane domain, and a carboxy terminal extracellular domain. OPG

binding proteins of the invention may be membrane-associated or may be in soluble form.

The invention provides for nucleic acids encoding an OPG binding protein, vectors and host cells expressing the polypeptide, and method for producing recombinant OPG binding protein. Antibodies or fragments thereof which specifically bind OPG binding protein are also provided.

OPG binding proteins may be used in assays to quantitate OPG levels in biological samples, identify cells and tissues that display OPG binding protein, and identify new OPG and OPG binding protein family members. Methods of identifying compounds which interact with OPG binding protein are also provided. Such compounds include nucleic acids, peptides, proteins, carbohydrates, lipids or small molecular weight organic molecules and may act either as agonists or antagonists of OPG binding protein activity.

OPG binding proteins are involved in osteoclast differentiation and the level of osteoclast activity in turn modulates bone resorption. OPG binding protein agonists and antagonists modulate osteoclast formation and bone resorption and may be used to treat bone diseases characterized by changes in bone resorption, such as osteoporosis, hypercalcemia, bone loss due to arthritis metastasis, immobilization or periodontal disease, Paget's disease, osteopetrosis, prosthetic loosening and the like. Pharmaceutical compositions comprising OPG binding proteins and OPG binding protein agonists and antagonists are also encompassed by the invention.

Description of the Figures

Figure 1. Structure and sequence of the 32D-F3 insert encoding OPG binding protein. Predicted

transmembrane domain and sites for asparagine-linked carbohydrate chains are underlined.

Figure 2. OPG binding protein expression in COS-7 cells transfected with pcDNA/32D-F3. Cells were lipofected with pcDNA/32D-F3 DNA, the assayed for binding to either goat anti-human IgG1 alkaline phosphatase conjugate (secondary alone), human OPG[22-201]-Fc plus secondary (OPG-Fc), or a chimeric ATAR extracellular domain-Fc fusion protein (sATAR-Fc). ATAR is a new member of the TNFR superfamily, and the sATAR-Fc fusion protein serves as a control for both human IgG1 Fc domain binding, and generic TNFR related protein, binding to 32D cell surface molecules.

Figure 3. Expression of OPG binding protein in human tissues. Northern blot analysis of human tissue mRNA (Clontech) using a radiolabeled 32D-F3 derived hybridization probe. Relative molecular mass is indicated at the left in kilobase pairs (kb). Arrowhead on right side indicates the migration of an approximately 2.5 kb transcript detected in lymph node mRNA. A very faint band of the same mass is also detected in fetal liver.

Figure 4. Structure and sequence of the pcDNA/ hu OPGbp 1.1 insert encoding the human OPG binding protein. The predicted transmembrane domain and site for asparagine-linked carbohydrate chains are underlined.

Figure 5. Stimulation of osteoclast development in vitro from bone marrow macrophage and ST2 cell cocultures treated with recombinant murine OPG binding protein [158-316]. Cultures were treated with varying concentrations of murine OPG binding protein

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binding protein, 51 hours after the first injection, and
in mice also receiving concurrent OPG administration.
OPG binding protein significantly and dose dependently
increased iCa levels. OPG (1mg/kg/day) completely
5 blocked the increase in iCa at a dose of OPG binding
protein of 5ug/day, and partially blocked the increase
at a dose of OPG binding protein of 25ug/day. (*),
different to vehicle treated control ($p < 0.05$). (#),
OPG treated iCa level significantly different to level
10 in mice receiving that dose of OPG binding protein alone
($p < 0.05$).

Figure 9. Radiographs of the left femur and
tibia in mice treated with 0, 5, 25 or 100ug/day of OPG
15 binding protein for 3.5 days. There is a dose dependent
decrease in bone density evident most clearly in the
proximal tibial metaphysis of these mice, and that is
profound at a dose of 100ug/day.

20 Detailed Description of the Invention

The invention provides for a polypeptide
referred to as an OPG binding protein, which
specifically binds OPG and is involved in osteoclast
differentiation. A cDNA clone encoding the murine form
25 of the polypeptide was identified from a library
prepared from a mouse myelomonocytic cell line 32-D and
transfected into COS cells. Transfectants were screened
for their ability to bind to an OPG[22-201]-Fc fusion
polypeptide (Example 1). The nucleic acid sequence
30 revealed that OPG binding protein is a novel member of
the TNF family and is most closely related to AGP-1, a
polypeptide previously described in co-owned and co-
pending U.S. Serial No. 08/660,562, filed June 7, 1996.
(A polypeptide identical to AGP-1 and designated TRAIL
35 is described in Wiley et al. Immunity 3, 673-682

(1995)). OPG binding protein is predicted to be a type II transmembrane protein having a cytoplasmic domain at the amino terminus, a transmembrane domain, and a carboxy terminal extracellular domain (Figure 1). The amino terminal cytoplasmic domain spans about residues 1-48, the transmembrane domain spans about residues 49-69 and the extracellular domain spans about residues 70-316 as shown in Figure 1 (SEQ ID NO:___). The membrane-associated protein specifically binds OPG (Figure 2). Thus OPG binding protein and OPG share many characteristics of a receptor-ligand pair although it is possible that other naturally-occurring receptors for OPG binding protein exist.

A DNA clone encoding human OPG binding protein was isolated from a lymph node cDNA library. The human sequence (Figure 4) is homologous to the murine sequence. Purified soluble murine OPG binding protein stimulated osteoclast formation in vitro and induced hypercalcemia and bone resorption in vivo.

OPG binding protein refers to a polypeptide having an amino acid sequence of mammalian OPG binding protein, or a fragment, analog, or derivative thereof, and having at least the activity of binding OPG. In preferred embodiments, OPG binding protein is of murine or human origin. In another embodiment, OPG binding protein is a soluble protein having, in one form, an isolated extracellular domain separate from cytoplasmic and transmembrane domains. OPG binding protein is involved in osteoclast differentiation and in the rate and extent of bone resorption, and was found to stimulate osteoclast formation and stimulate bone resorption.

Nucleic Acids

The invention provides for isolated nucleic acids encoding OPG binding proteins. As used herein, the term nucleic acid comprises cDNA, genomic DNA, wholly or partially synthetic DNA, and RNA. The nucleic acids of the invention are selected from the group consisting of:

a) the nucleic acids as shown in Figure 1 (SEQ ID NO: ____) and Figure 4 (SEQ ID NO: ____);

b) nucleic acids which hybridize to the polypeptide coding regions of the nucleic acids shown in Figure 1 (SEQ ID NO: ____) and Figure 4 (SEQ ID NO: ____); and remain hybridized to the nucleic acids under high stringency conditions; and

c) nucleic acids which are degenerate to the nucleic acids of (a) or (b).

Nucleic acid hybridizations typically involve a multi-step process comprising a first hybridization step to form nucleic acid duplexes from single strands followed by a second hybridization step carried out under more stringent conditions to selectively retain nucleic acid duplexes having the desired homology. The conditions of the first hybridization step are generally not crucial, provided they are not of higher stringency than the second hybridization step. Generally, the second hybridization is carried out under conditions of high stringency, wherein "high stringency" conditions refers to conditions of temperature and salt which are about 12-20°C below the melting temperature (T_m) of a perfect hybrid of part or all of the complementary strands corresponding to Figure 1 (SEQ. ID. NO: ____) and Figure 4 (SEQ ID NO: ____). In one embodiment, "high stringency" conditions refer to conditions of about 65°C and not more than about 1M Na+. It is understood that

salt concentration, temperature and/or length of incubation may be varied in either the first or second hybridization steps such that one obtains the hybridizing nucleic acid molecules according to the invention. Conditions for hybridization of nucleic acids and calculations of T_m for nucleic acid hybrids are described in Sambrook et al. Molecular Cloning: A Laboratory Manual Cold Spring Harbor Laboratory Press, New York (1989).

The nucleic acids of the invention may hybridize to part or all of the polypeptide coding regions of OPG binding protein as shown in Figure 1 (SEQ ID NO: ____) and Figure 4 (SEQ ID NO: ____); and therefore may be truncations or extensions of the nucleic acid sequences shown therein. Truncated or extended nucleic acids are encompassed by the invention provided that they retain at least the property of binding OPG. In one embodiment, the nucleic acid will encode a polypeptide of at least about 10 amino acids. In another embodiment, the nucleic acid will encode a polypeptide of at least about 20 amino acids. In yet another embodiment, the nucleic acid will encode a polypeptide of at least about 50 amino acids. The hybridizing nucleic acids may also include noncoding sequences located 5' and/or 3' to the OPG binding protein coding regions. Noncoding sequences include regulatory regions involved in expression of OPG binding protein, such as promoters, enhancer regions, translational initiation sites, transcription termination sites and the like.

In preferred embodiments, the nucleic acids of the invention encode mouse or human OPG binding protein. Nucleic acids may encode a membrane bound form of OPG binding protein or soluble forms which lack a functional transmembrane region. The predicted transmembrane

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region for murine OPG binding protein includes amino acid residues 49-69 inclusive as shown in Figure 1 (SEQ. ID. NO: ____). The predicted transmembrane region for human OPG binding protein includes residues 49-69 as shown in Figure 4 (SEQ ID NO:____). Substitutions which replace hydrophobic amino acid residues in this region with neutral or hydrophilic amino acid residues would be expected to disrupt membrane association and result in soluble OPG binding protein. In addition, deletions of part or all the transmembrane region would also be expected to produce soluble forms of OPG binding protein. Nucleic acids encoding amino acid residues 70-316 as shown in Figure 1 (SEQ ID NO:____), or fragments and analogs thereof, encompass soluble OPG binding proteins.

Nucleic acids encoding truncated forms of soluble human OPG binding proteins are also included. Soluble forms include residues 69-317 as shown in Figure 4 (SEQ ID NO: ____) and truncations thereof. In one embodiment, N-terminal truncations generate polypeptides from residues, 70-317, 71-317, 72-317, and so forth. In another embodiment, nucleic acids encode soluble OPGbp comprising residues 69-317 and N-terminal truncations thereof up to OPGbp [158-317], or alternatively, up to OPGbp [166-317].

Plasmid phuOPGbp 1.1 in E. coli strain DH10 encoding human OPG binding protein was deposited with the American Type Culture Collection, Rockville, MD on June 13, 1997.

Nucleic acid sequences of the invention may be used for the detection of sequences encoding OPG binding protein in biological samples. In particular, the sequences may be used to screen cDNA and genomic libraries for related OPG binding protein sequences, especially those from other species. The nucleic acids are also useful for modulating levels of OPG binding

protein by anti-sense technology or in vivo gene
expression. Development of transgenic animals
expressing OPG binding protein is useful for production
of the polypeptide and for the study of in vivo
5 biological activity.

Vectors and Host Cells

The nucleic acids of the invention will be
linked with DNA sequences so as to express biologically
10 active OPG binding protein. Sequences required for
expression are known to those skilled in the art and
include promoters and enhancer sequences for initiation
of RNA synthesis, transcription termination sites,
ribosome binding sites for the initiation of protein
15 synthesis, and leader sequences for secretion.
Sequences directing expression and secretion of OPG
binding protein may be homologous, i.e., the sequences
are identical or similar to those sequences in the
genome involved in OPG binding protein expression and
20 secretion, or they may be heterologous. A variety of
plasmid vectors are available for expressing OPG binding
protein in host cells (see, for example, Methods in
Enzymology v. 185, Goeddel, D.V. ed., Academic Press
(1990)). For expression in mammalian host cells, a
25 preferred embodiment is plasmid pDSR α described in
PCT Application No. 90/14363. For expression in
bacterial host cells, preferred embodiments include
plasmids harboring the lux promoter (see co-owned and
co-pending U.S. Serial No. 08/577,778, filed December
30 22, 1995). In addition, vectors are available for the
tissue-specific expression of OPG binding protein in
transgenic animals. Retroviral and adenovirus-based
gene transfer vectors may also be used for the
expression of OPG binding protein in human cells for in
35 vivo therapy (see PCT Application No. 86/00922).

Procaryotic and eucaryotic host cells expressing OPG binding protein are also provided by the invention. Host cells include bacterial, yeast, plant, insect or mammalian cells. OPG binding protein may also
5 be produced in transgenic animals such as mice or goats. Plasmids and vectors containing the nucleic acids of the invention are introduced into appropriate host cells using transfection or transformation techniques known to one skilled in the art. Host cells may contain DNA
10 sequences encoding OPG binding protein as shown in Figure 1 or a portion thereof, such as the extracellular domain or the cytoplasmic domain. Nucleic acids encoding OPG binding proteins may be modified by substitution of codons which allow for optimal
15 expression in a given host. At least some of the codons may be so-called preference codons which do not alter the amino acid sequence and are frequently found in genes that are highly expressed. However, it is understood that codon alterations to optimize expression
20 are not restricted to the introduction of preference codons. Examples of preferred mammalian host cells for OPG binding protein expression include, but are not limited to COS, CHOD-, 293 and 3T3 cells. A preferred bacterial host cell is Escherichia coli.

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Polypeptides

The invention also provides OPG binding protein as the product of procaryotic or eucaryotic expression of an exogenous DNA sequence, i.e., OPG
30 binding protein is recombinant OPG binding protein. Exogenous DNA sequences include cDNA, genomic DNA and synthetic DNA sequences. OPG binding protein may be the product of bacterial, yeast, plant, insect or mammalian cells expression, or from cell-free translation systems.
35 OPG binding protein produced in bacterial cells will

have an N-terminal methionine residue. The invention also provides for a process of producing OPG binding protein comprising growing procaryotic or eucaryotic host cells transformed or transfected with nucleic acids
5 encoding OPG binding protein and isolating polypeptide expression products of the nucleic acids.

Polypeptides which are mamalian OPG binding proteins or are fragments, analogs or derivatives thereof are encompassed by the invention. In a
10 preferred embodiment, the OPG binding protein is human OPG binding protein. A fragment of OPG binding protein refers to a polypeptide having a deletion of one or more amino acids such that the resulting polypeptide has at least the property of binding OPG. Said fragments will
15 have deletions originating from the amino terminal end, the carboxy terminal end, and internal regions of the polypeptide. Fragments of OPG binding protein are at least about ten amino acids, at least about 20 amino acids, or at least about 50 amino acids in length. In
20 preferred embodiments, OPG binding protein will have a deletion of one or more amino acids from the transmembrane region (amino acid residues 49-69 as shown in Figure 1), or, alternatively, one or more amino acids from the amino-terminus up to and/or including the
25 transmembrane region (amino acid residues 1-49 as shown in Figure 1). In another embodiment, OPG binding protein is a soluble protein comprising, for example, amino acid residues 69-316, or 70-316, or N-terminal or C-terminal truncated forms thereof, which retain OPG
30 binding activity. OPG binding protein is also a human soluble protein as shown in Figure 4 comprising residues 69-317 as shown in Figure 4 and N-terminal truncated forms thereof, e.g., 70-517, 71-517, 71-317, 72-317 and so forth. In a preferred embodiment, the soluble human
35 OPG binding protein comprising residues 69-317 and

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N-terminal truncation thereof up to OPGbp [158-317], or alternatively up to OPG [166-317].

5 An analog of an OPG binding protein refers to a polypeptide having a substitution or addition of one or more amino acids such that the resulting polypeptide has at least the property of binding OPG. Said analogs will have substitutions or additions at any place along the polypeptide. Preferred analogs include those of soluble OPG binding proteins. Fragments or analogs may be naturally occurring, such as a polypeptide product of an allelic variant or a mRNA splice variant, or they may be constructed using techniques available to one skilled in the art for manipulating and synthesizing nucleic acids. The polypeptides may or may not have an amino terminal methionine residue

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Also included in the invention are derivatives of OPG binding protein which are polypeptides that have undergone post-translational modifications (e.g., addition of N-linked or O-linked carbohydrate chains, processing of N-terminal or C-terminal ends), attachment of chemical moieties to the amino acid backbone, chemical modifications of N-linked or O-linked carbohydrate chains, and addition of an N-terminal methionine residue as a result of procaryotic host cell expression. In particular, chemically modified derivatives of OPG binding protein which provide additional advantages such as increased stability, longer circulating time, or decreased immunogenicity are contemplated. Of particular use is modification with water soluble polymers, such as polyethylene glycol and derivatives thereof (see for example U.S. Patent No. 4,179,337). The chemical moieties for derivitization may be selected from water soluble polymers such as polyethylene glycol, ethylene glycol/propylene glycol copolymers, carboxymethylcellulose, dextran, polyvinyl alcohol and

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the like. The polypeptides may be modified at random positions within the molecule, or at predetermined positions within the molecule and may include one, two, three or more attached chemical moieties. Polypeptides
5 may also be modified at pre-determined positions in the polypeptide, such as at the amino terminus, or at a selected lysine or arginine residue within the polypeptide. Other chemical modifications provided include a detectable label, such as an enzymatic,
10 fluorescent, isotopic or affinity label to allow for detection and isolation of the protein.

OPG binding protein chimeras comprising part or all of an OPG binding protein amino acid sequence fused to a heterologous amino acid sequence are also
15 included. The heterologous sequence may be any sequence which allows the resulting fusion protein to retain the at least the activity of binding OPG. In a preferred embodiment, the carboxy terminal extracellular domain of OPG binding protein is fused to a heterologous sequence.
20 Such sequences include heterologous cytoplasmic domains that allow for alternative intracellular signalling events, sequences which promote oligomerization such as the Fc region of IgG, enzyme sequences which provide a label for the polypeptide, and sequences which provide
25 affinity probes, such as an antigen-antibody recognition.

The polypeptides of the invention are isolated and purified from tissues and cell lines which express OPG binding protein, either extracted from lysates or
30 from conditioned growth medium, and from transformed host cells expressing OPG binding protein. OPG binding protein may be obtained from murine myelomonocytic cell line 32-D (ATCC accession no. CRL-11346). Human OPG binding protein, or nucleic acids encoding same, may be
35 isolated from human lymph node or fetal liver tissue.

Isolated OPG binding protein is free from association with human proteins and other cell constituents.

A method for the purification of OPG binding protein from natural sources (e.g. tissues and cell lines which normally express OPG binding protein) and from transfected host cells is also encompassed by the invention. The purification process may employ one or more standard protein purification steps in an appropriate order to obtain purified protein. The chromatography steps can include ion exchange, gel filtration, hydrophobic interaction, reverse phase, chromatofocusing, affinity chromatography employing an anti-OPG binding protein antibody or biotin-streptavidin affinity complex and the like.

Antibodies

Antibodies specifically binding the polypeptides of the invention are also encompassed by the invention. The antibodies may be produced by immunization with full-length OPG binding protein, soluble forms of OPG binding protein, or a fragment thereof. The antibodies of the invention may be polyclonal or monoclonal, or may be recombinant antibodies, such as chimeric antibodies wherein the murine constant regions on light and heavy chains are replaced by human sequences, or CDR-grafted antibodies wherein only the complementary determining regions are of murine origin. Antibodies of the invention may also be human antibodies prepared, for example, by immunization of transgenic animals capable of producing human antibodies (see, for example, PCT Application No. WO93/12227). The antibodies are useful for detecting OPG binding protein in biological samples, thereby allowing the identification of cells or tissues which produce the protein. In addition, antibodies which bind to OPG binding protein and block interaction with

other binding compounds may have therapeutic use in modulating osteoclast differentiation and bone resorption.

Antibodies to the OPG binding protein may be
5 useful in treatment of bone diseases such as,
osteoporosis and Paget's disease. Antibodies can be
tested for binding to the OPG binding protein in the
absence or presence of OPG and examined for their
ability to inhibit ligand (OPG binding protein) mediated
10 osteoclastogenesis and/or bone resorption. It is also
anticipated that the peptides themselves may act as an
antagonist of the ligand:receptor interaction and
inhibit ligand-mediated osteoclastogenesis, and peptides
of the OPG binding protein will be explored for this
15 purpose as well.

Compositions

The invention also provides for pharmaceutical
20 compositions comprising a therapeutically effective
amount of the OPG binding protein of the invention
together with a pharmaceutically acceptable diluent,
carrier, solubilizer, emulsifier, preservative and/or
adjuvant. The invention also provides for
25 pharmaceutical compositions comprising a therapeutically
effective amount of an OPG binding protein agonist or
antagonist. The term "therapeutically effective amount"
means an amount which provides a therapeutic effect for
a specified condition and route of administration. The
30 composition may be in a liquid or lyophilized form and
comprises a diluent (Tris, acetate or phosphate buffers)
having various pH values and ionic strengths,
solubilizer such as Tween or Polysorbate, carriers such
as human serum albumin or gelatin, preservatives such as
35 thimerosal or benzyl alcohol, and antioxidants such as

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ascrobic acid or sodium metabisulfite. Selection of a particular composition will depend upon a number of factors, including the condition being treated, the route of administration and the pharmacokinetic parameters desired. A more extensive survey of component suitable for pharmaceutical compositions is found in Remington's Pharmaceutical Sciences, 18th ed. A.R. Gennaro, ed. Mack, Easton, PA (1980).

In a preferred embodiment, compositions comprising soluble OPG binding proteins are also provided. Also encompassed are compositions comprising soluble OPG binding protein modified with water soluble polymers to increase solubility, stability, plasma half-life and bioavailability. Compositions may also comprise incorporation of soluble OPG binding protein into liposomes, microemulsions, micelles or vesicles for controlled delivery over an extended period of time. Soluble OPG binding protein may be formulated into microparticles suitable for pulmonary administration.

Compositions of the invention may be administered by injection, either subcutaneous, intravenous or intramuscular, or by oral, nasal, pulmonary or rectal administration. The route of administration eventually chosen will depend upon a number of factors and may be ascertained by one skilled in the art.

The invention also provides for pharmaceutical compositions comprising a therapeutically effective amount of the nucleic acids of the invention together with a pharmaceutically acceptable adjuvant. Nucleic acid compositions will be suitable for the delivery of part or all of the coding region of OPG binding protein and/or flanking regions to cells and tissues as part of an anti-sense therapy regimen.

Methods of Use

OPG binding proteins may be used in a variety of assays for detecting OPG and characterizing interactions with OPG. In general, the assay comprises
5 incubating OPG binding protein with a biological sample containing OPG under conditions which permit binding to OPG to OPG binding protein, and measuring the extent of binding. OPG may be purified or present in mixtures, such as in body fluids or culture medium. Assays may be
10 developed which are qualitative or quantitative, with the latter being useful for determining the binding parameters (affinity constants and kinetics) of OPG to OPG binding protein and for quantitating levels of biologically active OPG in mixtures. Assays may also be
15 used to evaluate the binding of OPG to fragments, analogs and derivatives of OPG binding protein and to identify new OPG and OPG binding protein family members.

Binding of OPG to OPG binding protein may be carried out in several formats, including cell-based
20 binding assays, membrane binding assays, solution-phase assays and immunoassays. In general, trace levels of labeled OPG are incubated with OPG binding protein samples for a specified period of time followed by measurement of bound OPG by filtration,
25 electrochemiluminescent (ECL, ORIGEN system by IGEN), cell-based or immunoassays. Homogeneous assay technologies for radioactivity (SPA; Amersham) and time resolved fluorescence (HTRF, Packard) can also be implemented. Binding is detected by labeling OPG or an
30 anti-OPG antibody with radioactive isotopes (^{125}I , ^{35}S , ^3H), fluorescent dyes (fluorescein), lanthanide (Eu^{3+}) chelates or cryptates, orbipyridyl-ruthenium (Ru^{2+}) complexes. It is understood that the choice of a labeled probe will depend upon the detection system
35 used. Alternatively, OPG may be modified with an

unlabeled epitope tag (e.g., biotin, peptides, His₆, myc) and bound to proteins such as streptavidin, anti-peptide or anti-protein antibodies which have a detectable label as described above.

5 In an alternative method, OPG binding protein may be assayed directly using polyclonal or monoclonal antibodies to OPG binding proteins in an immunoassay. Additional forms of OPG binding proteins containing epitope tags as described above may be used in solution
10 and immunoassays.

Methods for indentifying compounds which interact with OPG binding protein are also encompassed by the invention. The method comprises incubating OPG binding protein with a compound under conditions which
15 permit binding of the compound to OPG binding protein, and measuring the extent of binding. The compound may be substantially purified or present in a crude mixture. Binding compounds may be nucleic acids, proteins, peptides, carbohydrates, lipids or small molecular
20 weight organic compounds. The compounds may be further characterized by their ability to increase or decrease OPG binding protein activity in order to determine whether they act as an agonist or an antagonist.

OPG binding proteins are also useful for
25 identification of intracellular proteins which interact with the cytoplasmic domain by a yeast two-hybrid screening process. As an example, hybrid constructs comprising DNA encoding the N-terminal 50 amino acids of an OPG binding protein fused to a yeast GAL4-DNA binding
30 domain may be used as a two-hybrid bait plasmid. Positive clones emerging from the screening may be characterized further to identify interacting proteins. This information may help elucidate a intracellular signaling mechanism associated with OPG binding protein

and provide intracellular targets for new drugs that modulate bone resorption.

OPG binding protein may be used to treat conditions characterized by excessive bone density. The
5 most common condition is osteopetrosis in which a genetic defect results in elevated bone mass and is usually fatal in the first few years of life. Osteopetrosis is preferably treated by administration of soluble OPG binding protein.

10 The invention also encompasses modulators (agonists and antagonists) of OPG binding protein and the methods for obtaining them. An OPG binding protein modulator may either increase or decrease at least one activity associated with OPG binding protein, such as
15 ability to bind OPG or some other interacting molecule or to regulate osteoclast maturation. Typically, an agonist or antagonist may be a co-factor, such as a protein, peptide, carbohydrate, lipid or small molecular weight molecule, which interacts with OPG binding
20 protein to regulate its activity. Potential polypeptide antagonists include antibodies which react with either soluble or membrane-associated forms of OPG binding protein, and soluble forms of OPG binding protein which comprise part or all of the extracellular domain of OPG
25 binding protein. Molecules which regulate OPG binding protein expression typically include nucleic acids which are complementary to nucleic acids encoding OPG binding protein and which act as anti-sense regulators of expression.

30 OPG binding protein is involved in controlling formation of mature osteoclasts, the primary cell type implicated in bone resorption. An increase in the rate of bone resorption (over that of bone formation) can lead to various bone disorders collectively referred to
35 as osteopenias, and include osteoporosis, osteomyelitis, hypercalcemia, osteopenia brought on by surgery or

steroid administration, Paget's disease, osteonecrosis, bone loss due to rheumatoid arthritis, periodontal bone loss, immobilization, prosthetic loosening and osteolytic metastasis. Conversely, a decrease in the rate of bone resorption can lead to osteopetrosis, a condition marked by excessive bone density. Agonists and antagonists of OPG binding protein modulate osteoclast formation and may be administered to patients suffering from bone disorders. Agonists and antagonists of OPG binding protein used for the treatment of osteopenias may be administered alone or in combination with a therapeutically effective amount of a bone growth promoting agent including bone morphogenic factors designated BMP-1 to BMP-12, transforming growth factor- β and TGF- β family members, fibroblast growth factors FGF-1 to FGF-10, interleukin-1 inhibitors, TNF α inhibitors, parathyroid hormone, E series prostaglandins, bisphosphonates and bone-enhancing minerals such as fluoride and calcium. Antagonists of OPG binding proteins may be particularly useful in the treatment of osteopenia.

The following examples are offered to more fully illustrate the invention, but are not construed as limiting the scope thereof.

Example 1

Identification of a cell line source for an OPG binding protein

30

Osteoprotegerin (OPG) negatively regulates osteoclastogenesis in vitro and in vivo. Since OPG is a TNFR-related protein, it is likely to interact with a TNF-related family member while mediating its effects.

35 With one exception, all known members of the TNF

superfamily are type II transmembrane proteins expressed on the cell surface. To identify a source of an OPG binding protein, recombinant OPG-Fc fusion proteins were used as immunoprobes to screen for OPG binding proteins located on the surface of various cell lines and primary hematopoietic cells.

Cell lines that grew as adherent cultures in vitro were treated using the following methods: Cells were plated into 24 well tissue culture plates (Falcon), then allowed to grow to approximately 80% confluency. The growth media was then removed, and the adherent cultures were washed with phosphate buffered saline (PBS) (Gibco) containing 1% fetal calf serum (FCS). Recombinant mouse OPG [22-194]-Fc and human OPG [22-201]-Fc fusion proteins (see U.S. Serial No. 08/706,945 filed September 3, 1996) were individually diluted to 5 ug/ml in PBS containing 1% FCS, then added to the cultures and allowed to incubate for 45 min at 0°C. The OPG-Fc fusion protein solution was discarded, and the cells were washed in PBS-FCS solution as described above. The cultures were then exposed to phycoerythrin-conjugated goat F(ab') anti-human IgG secondary antibody (Southern Biotechnology Associates Cat. # 2043-09) diluted into PBS-FCS. After a 30-45 min incubation at 0°C, the solution was discarded, and the cultures were washed as described above. The cells were then analysed by immunofluorescent microscopy to detect cell lines which express a cell surface OPG binding protein.

Suspension cell cultures were analysed in a similar manner with the following modifications: The diluent and wash buffer consisted of calcium- and magnesium-free phosphate buffered saline containing 1% FCS. Cells were harvested from exponentially replicating cultures in growth media, pelleted by centrifugation, then resuspended at 1×10^7 cells/ml in a

96 well microtiter tissue culture plate (Falcon). Cells were sequentially exposed to recombinant OPG-Fc fusion proteins, then secondary antibody as described above, and the cells were washed by centrifugation between each
5 step. The cells were then analysed by fluorescence activated cell sorting (FACS) using a Becton Dickinson FACscan.

Using this approach, the murine myelomonocytic cell line 32D (ATCC accession no. CRL-11346) was found
10 to express a surface molecule which could be detected with both the mouse OPG[22-194]-Fc and the human OPG[22-201]-Fc fusion proteins. Secondary antibody alone did not bind to the surface of 32D cells nor did
15 purified human IgG1 Fc, indicating that binding of the OPG-Fc fusion proteins was due to the OPG moiety. This binding could be competed in a dose dependent manner by the addition of recombinant murine or human OPG[22-401] protein. Thus the OPG region required for its biological
20 activity is capable of specifically binding to a 32D-derived surface molecule.

Example 2

Expression cloning of a murine OPG binding protein

25

A cDNA library was prepared from 32D mRNA, and ligated into the mammalian expression vector pCDNA3.1(+) (Invitrogen, San Diego, CA). Exponentially growing 32D cells maintained in the presence of recombinant
30 interleukin-3 were harvested, and total cell RNA was purified by acid guanidinium thiocyanate-phenol-chloroform extraction (Chomczynski and Sacchi. Anal. Biochem. 162, 156-159, (1987)). The poly (A+) mRNA fraction was obtained from the total RNA preparation by
35 adsorption to, and elution from, Dynabeads Oligo (dT)25

(Dynal Corp) using the manufacturer's recommended procedures. A directional, oligo-dT primed cDNA library was prepared using the Superscript Plasmid System (Gibco BRL, Gaithersburg, Md) using the manufacturer's
5 recommended procedures. The resulting cDNA was digested to completion with Sal I and Not I restriction endonuclease, then fractionated by size exclusion gel chromatography. The highest molecular weight fractions were selected, and then ligated into the polyliker
10 region of the plasmid vector pcDNA3.1(+) (Invitrogen, San Diego, CA). This vector contains the CMV promotor upstream of multiple cloning site, and directs high level expression in eukaryotic cells. The library was then electroporated into competent E. coli (ElectroMAX
15 DH10B, Gibco, NY), and titered on LB agar containing 100 ug/ml ampicillin. The library was then arrayed into segregated pools containing approximately 1000 clones/pool, and 1.0 ml cultures of each pool were grown for 16-20 hr at 37°C. Plasmid DNA from each culture was
20 prepared using the Qiagen QiaWell 96 Ultra Plasmid Kit (catalog #16191) following manufacturer's recommended procedures.

Arrayed pools of 32D cDNA expression library were individually lipofected into COS-7 cultures, then
25 assayed for the acquisition of a cell surface OPG binding protein. To do this, COS-7 cells were plated at a density of 1×10^6 per ml in six-well tissue culture plates (Costar), then cultured overnight in DMEM (Gibco) containing 10% FCS. Approximately 2 μ g of plasmid DNA
30 from each pool was diluted into 0.5 ml of serum-free DMEM, then sterilized by centrifugation through a 0.2 μ m Spin-X column (Costar). Simultaneously, 10 μ l of Lipofectamine (Life Technologies Cat # 18324-012) was added to a separate tube containing 0.5ml of serum-free

DMEM. The DNA and Lipofectamine solutions were mixed, and allowed to incubate at RT for 30 min. The COS-7 cell cultures were then washed with serum-free DMEM, and the DNA-lipofectamine complexes were exposed to the
5 cultures for 2-5 hr at 37°C. After this period, the media was removed, and replaced with DMEM containing 10%FCS. The cells were then cultured for 48 hr at 37°C.

To detect cultures that express an OPG binding protein, the growth media was removed, and the cells
10 were washed with PBS-FCS solution. A 1.0 ml volume of PBS-FCS containing 5 µg/ml of human OPG[22-201]-Fc fusion protein was added to each well and incubated at RT for 1 hr. The cells were washed three times with PBS-FCS solution, and then fixed in PBS containing 2%
15 paraformaldehyde and 0.2% glutaraldehyde in PBS at RT for 5 min. The cultures were washed once with PBS-FCS, then incubated for 1 hr at 65°C while immersed in PBS-FCS solution. The cultures were allowed to cool, and the PBS-FCS solution was aspirated. The cultures
20 were then incubated with an alkaline-phosphatase conjugated goat anti-human IgG (Fc specific) antibody (SIGMA Product # A-9544) at Rt for 30 min, then washed three-times with 20 mM Tris-Cl (pH 7.6), and 137 mM NaCl. Immune complexes that formed during these steps
25 were detected by assaying for alkaline phosphatase activity using the Fast Red TR/AS-MX Substrate Kit (Pierce, Cat. # 34034) following the manufacturer's recommended procedures.

Using this approach, a total of approximately
30 300,000 independent 32D cDNA clones were screened, represented by 300 transfected pools of 1000 clones each. A single well was identified that contained cells which acquired the ability to be specifically decorated by the OPG-Fc fusion protein. This pool was subdivided
35 by sequential rounds of sib selection, yeilding a single

plasmid clone 32D-F3 (Figure 1). 32D-F3 plasmid DNA was then transfected into COS-7 cells, which were immunostained with either FITC-conjugated goat anti-human IgG secondary antibody alone, human OPG[22-201]-Fc fusion protein plus secondary, or with ATAR-Fc fusion protein (ATAR also known as HVEM; Montgomery et al. Cell 87, 427-436 (1996)) (Figure 2). The secondary antibody alone did not bind to COS-7/32D-F3 cells, nor did the ATAR-Fc fusion protein. Only the OPG Fc fusion protein bound to the COS-7/32D-F3 cells, indicating that 32D-F3 encoded an OPG binding protein displayed on the surface of expressing cells.

Example 3

OPG Binding Protein Sequence

The 32D-F3 clone isolated above contained an approximately 2.3 kb cDNA insert (Figure 1), which was sequenced in both directions on an Applied Biosystems 373A automated DNA sequencer using primer-driven Taq dye-terminator reactions (Applied Biosystems) following the manufacturer's recommended procedures. The resulting nucleotide sequence obtained was compared to the DNA sequence database using the FASTA program (GCG, Univeristy of Wisconsin), and analysed for the presence of long open reading frames (LORF's) using the "Six-way open reading frame" application (Frames) (GCG, Univeristy of Wisconsin). A LORF of 316 amino acid (aa) residues beginning at methionine was detected in the appropriate orientation, and was preceded by a 5' untranslated region of about 150 bp. The 5' untranslated region contained an in-frame stop codon upstream of the predicted start codon. This indicates that the structure of the 32D-F3 plasmid is consistent

with its ability to utilize the CMV promotor region to direct expression of a 316 aa gene product in mammalian cells.

5 The predicted OPG binding protein sequence was then compared to the existing database of known protein sequences using a modified version of the FASTA program (Pearson, Meth. Enzymol. 183, 63-98 (1990)). The amino acid sequence was also analysed for the presence of specific motifs conserved in all known members of the
10 tumor necrosis factor (TNF) superfamily using the sequence profile method of (Gribskov et al. Proc. Natl. Acad. Sci. USA 83, 4355-4359 (1987)), as modified by L  thy et al. Protein Sci. 3, 139-146 (1994)). There appeared to be significant homology throughout the OPG
15 binding protein to several members of the TNF superfamily. The mouse OPG binding protein appear to be most closely related to the mouse and human homologs of both TRAIL and CD40 ligand. Further analysis of the OPG binding protein sequence indicated a strong match to the
20 TNF superfamily, with a highly significant Z score of 19.46.

The OPG binding protein amino acid sequence contains a probable hydrophobic transmembrane domain that begins at a M49 and extends to L69. Based on this
25 configuration relative to the methionine start codon, the OPG binding protein is predicted to be a type II transmembrane protein, with a short N-terminal intracellular domain, and a longer C-terminal extracellular domain (Figure 4). This would be similar
30 to all known TNF family members, with the exception of lymphotoxin alpha (Nagata and Golstein, Science 267, 1449-1456 (1995)).

Example 4

Expression of human OPG binding protein mRNA

5 Multiple human tissue northern blots
(Clontech, Palo Alto, CA) were probed with a ^{32}P -dCTP
labelled 32D-F3 restriction fragment to detect the size
of the human transcript and to determine patterns of
expression. Northern blots were prehybridized in 5X
10 SSPE, 50% formamide, 5X Denhardt's solution, 0.5% SDS,
and 100 $\mu\text{g/ml}$ denatured salmon sperm DNA for 2-4 hr at
42°C. The blots were then hybridized in 5X SSPE, 50%
formamide, 2X Denhardt's solution, 0.1% SDS, 100 $\mu\text{g/ml}$
denatured salmon sperm DNA, and 5 ng/ml labelled probe
15 for 18-24 hr at 42°C. The blots were then washed in 2X
SSC for 10 min at RT, 1X SSC for 10 min at 50°C, then in
0.5X SSC for 10-15 min.

Using a probe derived from the mouse cDNA and
hybridization under stringent conditions, a predominant
20 mRNA species with a relative molecular mass of about 2.5
kb was detected in lymph nodes (Figure 3). A faint
signal was also detected at the same relative molecular
mass in fetal liver mRNA. No OPG binding protein
transcripts were detected in the other tissues examined.
25 The data suggest that expression of OPG binding protein
mRNA was extremely restricted in human tissues. The
data also indicate that the cDNA clone isolated is very
close to the size of the native transcript, suggesting
32D-F3 is a full length clone.

Example 5

Molecular cloning of the human OPG binding protein

5 The human homolog of the OPG binding protein
is expressed as an approximately 2.5 kb mRNA in human
peripheral lymph nodes and is detected by hybridization
with a mouse cDNA probe under stringent hybridization
conditions. DNA encoding human OPG binding protein is
10 obtained by screening a human lymph node cDNA library by
either recombinant bacteriophage plaque, or transformed
bacterial colony, hybridization methods (Sambrook et
al. Molecular Cloning: A Laboratory Manual Cold Spring
Harbor Press, New York (1989)). To this the phage or
15 plasmid cDNA library are screened using radioactively-
labeled probes derived from the murine OPG binding
protein clone 32D-F3. The probes are used to screen
nitrocellulose filter lifted from a plated library.
These filters are prehybridized and then hybridized
20 using conditions specified in Example 4, ultimately
giving rise to purified clones of the human OPG binding
protein cDNA. Inserts obtained from any human OPG
binding protein clones would be sequenced and analysed
as described in Example 3.

25 A human lymph node poly A+ RNA (Clontech,
Inc., Palo Alto, CA) was analysed for the presence of
OPG-bp transcripts as previously in U.S. Serial No.
08/577,788, filed December 22, 1995. A northern blot of
this RNA sample probed under stringent conditions with a
30 32P-labeled mouse OPG-bp probe indicated the presence of
human OPG-bp transcripts. An oligo dT-primed cDNA
library was then synthesized from the lymph node mRNA
using the SuperScript kit (GIBCO life Technologies,
Gaithersburg, MD) as described in example 2. The
35 resulting cDNA was size selected, and the high molecular

fraction ligated to plasmid vector pcDNA 3.1 (+)
(Invitrogen, San Diego, CA). Electrocompetent E. coli
DH10 (GIBCO life Technologies, Gaithersburg, MD) were
transformed, and 1×10^6 ampicillin resistant
5 transformants were screened by colony hybridization
using a ^{32}P -labeled mouse OPG binding protein probe.

A plasmid clone of putative human OPG binding
protein cDNA was isolated, phuOPGbp-1.1, and contained a
2.3 kp insert. The resulting nucleotide sequence of the
10 phuOPGbp-1.1 insert was approximately 80-85% homologous
to the mouse OPG binding protein cDNA sequence.
Translation of the insert DNA sequence indicated the
presence of a long open reading frame predicted to
encode a 317 aa polypeptide (Figure 4). Comparison of
15 the mouse and human OPG-bp polypeptides shows that they
are ~87% identical, indicating that this protein is
highly conserved during evolution.

The human OPG binding protein DNA and protein
sequences were not present in Genbank, and there were no
20 homologus EST sequences. As with the murine homolog,
the human OPG binding protein shows strong sequence
similarity to all members of the $\text{TNF}\alpha$ superfamily of
cytokines.

25

Example 6

Cloning and Bacterial Expression of OPG binding protein

PCR amplification employing the primer pairs
30 and templates described below are used to generate
various forms of murine OPG binding proteins. One
primer of each pair introduces a TAA stop codon and a
unique XhoI or SacII site following the carboxy terminus
of the gene. The other primer of each pair introduces a
35 unique NdeI site, a N-terminal methionine, and optimized

codons for the amino terminal portion of the gene. PCR and thermocycling is performed using standard recombinant DNA methodology. The PCR products are purified, restriction digested, and inserted into the unique NdeI and XhoI or SacII sites of vector pAMG21 (ATCC accession no. 98113) and transformed into the prototrophic E. coli 393 or 2596. Other commonly used E. coli expression vectors and host cells are also suitable for expression. After transformation, the clones are selected, plasmid DNA is isolated and the sequence of the OPG binding protein insert is confirmed.

pAMG21-Murine OPG binding protein [75-316]

This construct was engineered to be 242 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met(75)-Asp-Pro-Asn-Arg-----Gln-Asp-Ile-Asp(316)-COOH. The template to be used for PCR was pCDNA/32D-F3 and oligonucleotides #1581-72 and #1581-76 were the primer pair to be used for PCR and cloning this gene construct.

1581-72:

5'-GTTCTCCTCATATGGATCCAAACCGTATTTCTGAAGACAGCACTCACTGCTT-3'

(SEQ ID NO:___)

1581-76:

5'-TACGCACTCCGCGGTTAGTCTATGTCCTGAACTTTGA-3'

(SEQ ID NO:___)

pAMG21-Murine OPG binding protein [95-316]

This construct was engineered to be 223 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met-His(95)-Glu-Asn-Ala-Gly-----Gln-Asp-Ile-Asp(316)-COOH. The template used for PCR was pCDNA/32D-F3 and oligonucleotides #1591-90 and

#1591-95 were the primer pair used for PCR and cloning this gene construct.

1591-90:

5 5'-ATTTGATTCTAGAAAGGAGGAATAACATATGCATGAAAACGCAGGTCTGCAG-3'
(SEQ ID NO:___)

1591-95:

5'-TATCCGCGGATCCTCGAGTTAGTCTATGTCCTGAACTTTGAA-3'
(SEQ ID NO:___)

10

pAMG21-Murine OPG binding protein [107-316]

This construct was engineered to be 211 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met-Ser(107)-Glu-Asp-Thr-Leu----
15 ---Gln-Asp-Ile-Asp(316)-COOH. The template used for PCR was pcDNA/32D-F3 and oligonucleotides #1591-93 and #1591-95 were the primer pair used for PCR and cloning this gene construct.

20

1591-93:

5'-ATTTGATTCTAGAAAGGAGGAATAACATATGTCTGAAGACACTCTGCCGGACTCC-3'
(SEQ ID NO:___)

1591-95:

5'-TATCCGCGGATCCTCGAGTTAGTCTATGTCCTGAACTTTGAA-3'
25 (SEQ ID NO:___)

pAMG21-Murine OPG binding protein [118-316]

This construct was engineered to be 199 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met(118)-Lys-Gln-Ala-Phe-Gln----
30 ---Gln-Asp-Ile-Asp(316)-COOH. The template used for PCR was pcDNA/32D-F3 and oligonucleotides #1591-94 and #1591-95 were the primer pair used for PCR and cloning
35 this gene construct.

1591-94:

5'-ATTTGATTCTAGAAAGGAGGAATAACATATGAAACAAGCTTTTCAGGGG-3'
(SEQ ID NO:___)

1591-95:

5'-TATCCGCGGATCCTCGAGTTAGTCTATGTCCTGAACTTTGAA-3'
(SEQ ID NO:___)

pAMG21-Murine OPG binding protein [128-316]

This construct was engineered to be 190 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met-Lys(128)-Glu-Leu-Gln-His-----Gln-Asp-Ile-Asp(316)-COOH. The template used for PCR was pcDNA/32D-F3 and oligonucleotides #1591-91 and #1591-95 were the primer pair used for PCR and cloning this gene construct.

1591-91:

5'-ATTTGATTCTAGAAAGGAGGAATAACATATGAAAGAACTGCAGCACATTGTG-3'
(SEQ ID NO:___)

1591-95:

5'-TATCCGCGGATCCTCGAGTTAGTCTATGTCCTGAACTTTGAA-3'
(SEQ ID NO:___)

pAMG21-Murine OPG binding protein [137-316]

This construct was engineered to be 181 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met-Gln(137)-Arg-Phe-Ser-Gly-----Gln-Asp-Ile-Asp(316)-COOH. The template used for PCR was pcDNA/32D-F3 and oligonucleotides #1591-92 and #1591-95 were the primer pair used for PCR and cloning this gene construct.

1591-92:

5'-ATTTGATTCTAGAAAGGAGGAATAACATATGCAGCGTTTCTCTGGTGCTCCA-3'

(SEQ ID NO:___)

5 1591-95:

5'-TATCCGCGGATCCTCGAGTTAGTCTATGTCCTGAACTTTGAA-3'

(SEQ ID NO:___)

10 pAMG21-Murine OPG binding protein [146-316]

This construct is engineered to be 171 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met(146)-Glu-Gly-Ser-Trp-----Gln-Asp-Ile-Asp(316)-COOH. The template to be used for PCR is pAMG21-murine OPG binding protein [75-316] described above and oligonucleotides #1600-98 and #1581-76 will be the primer pair to be used for PCR and cloning this gene construct.

20 1600-98:

5'-GTTCTCCTCATATGGAAGGTTCTTGGTTGGATGTGGCCCA-3'

(SEQ ID NO:___)

1581-76:

5'-TACGCACTCCGCGGTTAGTCTATGTCCTGAACTTTGA-3'

25 (SEQ ID NO:___)

pAMG21-Murine OPG binding protein [156-316]

This construct is engineered to be 162 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met-Arg(156)-Gly-Lys-Pro-----Gln-Asp-Ile-Asp(316)-COOH. The template to be used for PCR is pAMG21-murine OPG binding protein [158-316] below and oligonucleotides #1619-86 and #1581-76 will be the primer pair to be used for PCR and cloning this gene construct.

1619-86:

5'- GTTCTCCTCATATGCGTGGTAAACCTGAAGCTCAACCATTGCA-3'
(SEQ ID NO:___)

1581-76:

5 - 5'-TACGCACTCCGCGGTTAGTCTATGTCCTGAACTTTGA-3'
(SEQ ID NO:___)

pAMG21-Murine OPG binding protein [158-316]

This construct was engineered to be 160 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met-Lys(158)-Pro-Glu-Ala-----Gln-Asp-Ile-Asp(316)- COOH. The template to be used for PCR was pcDNA/32D-F3 and oligonucleotides #1581-73 and #1581-76 were the primer pair to be used for PCR and cloning this gene construct.

1581-73:

5'-GTTCTCCTCATATGAAACCTGAAGCTCAACCATTGTCACACCTCACCATCAAT-3'
(SEQ ID NO:___)

20 1581-76:

5'-TACGCACTCCGCGGTTAGTCTATGTCCTGAACTTTGA-3'
(SEQ ID NO:___)

pAMG21-Murine OPG binding protein [166-316]

This construct is engineered to be 152 amino acids in length and have the following N-terminal and C-terminal residues, NH₂-Met-His(166)-Leu-Thr-Ile-----Gln-Asp-Ile-Asp(316)- COOH. The template to be used for PCR is pcDNA/32D-F3 and oligonucleotides #1581-75 and #1581-76 will be the primer pair to be used for PCR and cloning this gene construct.

1581-75:

5'-GTTCTCCTCATATGCATTTAACTATTAACGCTGCATCTATCCCAT
CGGGTTCCTCATAAAGTCACT-3' (SEQ ID NO:___)

5 1581-76:

5'-TACGCACTCCGCGGTTAGTCTATGTCCTGAACTTTGA-3' (SEQ ID NO:___)

pAMG21-Murine OPG binding protein [168-316]

10 This construct is engineered to be 150 amino
acids in length and have the following N-terminal and
C-terminal residues, NH₂-Met-Thr(168)-Ile-Asn-Ala-----
Gln-Asp-Ile-Asp(316)-COOH. The template to be used for
PCR is pcDNA/32D-F3 and oligonucleotides #1581-74 and
#1581-76 will be the primer pair to be used for PCR and
15 cloning.

1581-74:

5'-GTTCTCCTCATATGACTATTAACGCTGCATCTATCCCATCGGGTTCCTCATAAAGTCACT-3'
(SEQ ID NO:___)

20 1581-76:

5'-TACGCACTCCGCGGTTAGTCTATGTCCTGAACTTTGA-3' (SEQ ID NO:___)

It is understood that the above constructs are examples
and one skilled in the art may readily obtain other
25 forms of OPG binding protein using the general
methodology presented her.

Recombinant bacterial constructs pAMG21-murine
OPG binding protein [75-316], [95-316], [107-316], [118-
316], [128-316], [137-316], and [158-316] have been
30 cloned, DNA sequence confirmed, and levels of
recombinant gene product expression following induction
has been examined. All constructs produced levels of
recombinant gene product which was readily visible
following SDS polyacrylamide gel electrophoresis and
35 coomassie staining of crude lysates. Growth of
transformed E. coli 393 or 2596, induction of OPG

binding protein expression and isolation of inclusion
bodies containing OPG binding protein is done according
to procedures described in U.S. Serial No. 08/577,788
filed December 22, 1995. Purification of OPG binding
5 proteins from inclusion bodies requires solubilization
and renaturing of OPG binding protein using procedures
available to one skilled in the art. Recombinant murine
OPG binding protein [158-316] was found to be produced
mostly insolubly, but about 40% was found in the soluble
10 fraction. Recombinant protein was purified from the
soluble fraction as described below and its bioactivity
examined.

15

Example 7

Purification of recombinant murine OPG ligand [158-316]

Frozen bacterial cells harboring expressed murine
OPG binding protein (158-316) were thawed and
20 resuspended in 20mM tris-HCl pH 7.0, 10mM EDTA. The cell
suspension (20%w/v) was then homogenized by three passes
through a microfluidizer. The lysed cell suspension was
centrifuged in a JA14 rotor at 10,000 rpm for 45
minutes. SDS-PAGE analysis showed a band of
25 approximately 18kd molecular weight present in both
inclusion bodies and the supernatant. The soluble
fraction was then applied to a Pharmacia SP Sepharose
4FF column equilibrated with 10mM MES pH 6.0. The OPG
binding protein was eluted with a 20 column volume
30 gradient of 0-0.4M NaCl in MES pH 6.0. Fractions
containing OPG binding protein were then applied to an
ABX Bakerbond column equilibrated with 20mM MES pH 6.0.
OPG binding protein was eluted with a 15CV gradient of
0-0.5M NaCl in MES pH 6.0. The final product was over
35 95% homogeneous by SDS-PAGE. N-terminal sequencing gave
the following sequence: Met-Lys-Pro-Glu-Ala-Gln-Pro-

Phe-Ala-His which was identified to that predicted for a polypeptide starting at residue 158 (with an initiator methionine). The relative molecular weight of the protein during SDS-PAGE does not change upon reduction.

5

Example 8

In vitro bioactivity of recombinant soluble OPG-bp

10 Recombinant OPG protein has previously been shown to block vitamin D3-dependent osteoclast formation from bone marrow and spleen precursors in an osteoclast forming assay as described in U.S. Serial No. 08/577,788. Since OPG binding protein binds to OPG, and
15 is a novel member of the TNF family of ligands, it is a potential target of OPG bioactivity. Recombinant soluble OPG binding protein (158-316), representing the minimal core TNF α -like domain, was tested for its ability to modulate osteoclast differentiation from
20 osteoclast precursors. Bone marrow cells were isolated from adult mouse femurs, and treated with M-CSF. The non-adherent fraction was co-cultured with ST2 cells in the presence and absence of both vitamin D3 and dexamethasone. As previously shown, osteoclasts develop
25 only from co-cultures containing stromal cells (ST2), vitamin D3 and dexamethasone. Recombinant soluble OPG binding protein was added at varying concentrations ranging from 0.16 to 500 ng/ml and osteoclast maturation was determined by TRAP solution assay and by visual
30 observation. OPG binding protein strongly stimulated osteoclast differentiation and maturation in a dose dependent manner, with half-maximal effects in the 1-2 ng/ml range, suggesting that it acts as an potent inducer of osteoclastogenesis in vitro (Figure 5). The

effect of OPG binding protein is blocked by recombinant OPG (Figure 6).

To test whether OPG binding protein could replace the stroma and added steroids, cultures were established using M-CSF at varying concentrations to promote the growth of osteoclast precursors and various amounts of OPG binding protein were also added. As shown in Figure 6, OPG binding protein dose dependently stimulated TRAP activity, and the magnitude of the stimulation was dependent on the level of added M-CSF suggesting that these two factors together are pivotal for osteoclast development. To confirm the biological relevance of this last observation, cultures were established on bovine cortical bone slices and the effects of M-CSF and OPG binding protein either alone or together were tested. As shown in Figure 7, OPG binding protein in the presence of M-CSF stimulated the formation of large TRAP positive osteoclasts that eroded the bone surface resulting in pits. Thus, OPG binding protein acts as an osteoclastogenesis stimulating (differentiation) factor. This suggests that OPG blocks osteoclast development by sequestering OPG binding protein.

Example 9

In vivo activity of recombinant soluble OPG Binding Protein

Based on in vitro studies, recombinant murine OPG binding protein [158-316] produced in E.coli is a potent inducer of osteoclast development from myeloid precursors. To determine its effects in vivo, male BDF1 mice aged 4-5 weeks (Charles River Laboratories) received subcutaneous injections of OPG binding protein

[158-316] twice a day for three days and on the morning of the fourth day (days 0, 1, 2, and 3). Five groups of mice (n=4) received carrier alone, or 1, 5, 25 or 100µg/ of of OPG binding protein [158-316] per day . An
5 additional 5 groups of mice (n=4) received the above doses of carrier or of OPG binding protein [158-316] and in addition received human Fc-OPG [22-194] at 1mg/Kg/day (approximately 20 µg/day) by single daily subcutaneous injection. Whole blood ionized calcium was determined
10 prior to treatment on day 0 and 3-4 hours after the first daily injection of of OPG binding protein [158-316] on days 1, 2, and 3. Four hours after the last injection on day 3 the mice were sacrificed and radiographs were taken.

15 Recombinant of OPG binding protein [158-316] produced a significant increase in blood ionized calcium after two days of treatment at dose of 5 µg/day and higher (Figure 8). The severity of the hypercalcemia indicates a potent induction of osteoclast activity
20 resulting from increased bone resorption. Concurrent OPG administration limited hypercalcemia at doses of OPG binding protein [158-316] of 5 and 25 µg/day, but not at 100 µg/day. These same animal were analysed by
25 radiaography to determine if there were any effects on bone mineral density visible by X-ray (Figure 9). Recombinant of OPG binding protein [158-316] injected for 3 days decreased bone density in the proximal tibia of mice in a dose-dependent manner. The reduction in bone density was particularly evident in mice receiving
30 100 µg/d confirming that the profound hypercalcemia in these animals was produced from increased bone resorption and the resulting release of calcium from the skeleton. These data clearly indicate that of OPG

binding protein [158-316] acts in vivo to promote bone resorption, leading to systemic hypercalcemia, and recombinant OPG abrogates these effects.

5

Example 10

Cloning and Expression of soluble OPG Binding Protein in mammalian cells

10 The full length clone of murine and human OPG binding protein can be expressed in mammalian cells as previously described in Example 2. Alternatively, the cDNA clones can be modified to encode secreted forms of the protein when expressed in mammalian cells. To do
15 this, the natural 5' end of the cDNA encoding the initiation codon, and extending approximately through the first 69 amino acid of the protein, including the transmembrane spanning region, could be replaced with a signal peptide leader sequence. For example, DNA
20 sequences encoding the initiation codon and signal peptide of a known gene can be spliced to the OPG binding protein cDNA sequence beginning anywhere after the region encoding amino acid residue 68. The resulting recombinant clones are predicted to produce
25 secreted forms of OPG binding protein in mammalian cells, and should undergo post translational modifications which normally occur in the C-terminal extracellular domain of OPG binding protein, such as glycosylation. Using this strategy, a secreted form of
30 OPG binding protein was constructed which has at its 5' end the murine OPG signal peptide, and at its 3' end the human IgG1 Fc domain. The plasmid vector pCEP4/muOPG[22-401]-Fc as described in U.S. Serial No. 08/577,788, filed December 22, 1995, was digested with
35 NotI to cleave between the 3' end of OPG and the Fc gene. The linearized DNA was then partially digested

with XmnI to cleave only between residues 23 and 24 of OPG leaving a blunt end. The restriction digests were then dephosphorylated with CIP and the vector portion of this digest (including residues 1-23 of OPG and Fc) was
5 gel purified.

The murine OPG binding protein cDNA region encoding amino acid residues 69-316 were PCR amplified using Pfu Polymerase (Stratagene, San Diego, CA) from the plasmid template using primers the following oligonucleotides:
10 1602-61: CCT CTA GGC CTG TAC TTT CGA GCG CAG ATG

1602-59: CCT CTG CGG CCG CGT CTA TGT CCT GAA CTT TG

The 1602-61 oligonucleotide amplifies the 5' end of the gene and contains an artificial an StuI site. The
15 1602-59 primer amplifies the 3' end of the gene and contains an artificial NotI site. The resulting PCR product obtained was digested with NotI and StuI, then gel purified. The purified PCR product was ligated with vector, then used to transform electrocompetent E. coli
20 DH10B cells. The resulting clone was sequenced to confirm the integrity of the amplified sequence and restriction site junctions. This plasmid was then used to transfect human 293 fibroblasts, and the OPG binding protein-Fc fusion protein was collected from culture
25 media as previously described in U.S. Serial No. 08/577,788, filed December 22, 1995.

Using a similar strategy, an expression vector was designed that is capable of expressing a N-terminal truncation of fused to the human IgG1 Fc domain. This
30 construct consists of the murine OPG signal peptide (aa residue 1-21), fused in frame to murine OPG binding protein residues 158-316, followed by an inframe fusion to human IgG1 Fc domain. To do this, the plasmid vector pCEP4/ murine OPG [22-401] (U.S. Serial No. 08/577,788,
35 filed December 22, 1995), was digested with HindIII and NotI to remove the entire OPG reading frame. Murine OPG

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binding protein, residues 158-316 were PCR amplified using from the plasmid template pCDNA/32D-F3 using the following primers:

1616-44: CCT CTC TCG AGT GGA CAA CCC AGA AGC CTG AGG CCC

5 AGC CAT TTG C

1602-59: CCT CTG CGG CCG CGT CTA TGT CCT GAA CTT TG

1616-44 amplifies OPG binding protein starting at residue 158 as well as containing residues 16-21 of the muOPG signal peptide with an artificial XhoI site.

10 1602-59 amplifies the 3' end of the gene and adds an in-frame NotI site. The PCR product was digested with NotI and XhoI and then gel purified.

The Following complimentary primers were annealed to eachother to form an adapter encoding the murine OPG
15 signal peptide and Kozak sequence surrounding the translation initiation site:

1616-41: AGC TTC CAC CAT GAA CAA GTG GCT GTG CTG CGC ACT
CCT GGT GCT CCT GGA CAT CA

20

1616-42: TCG ATG ATG TCC AGG AGC ACC AGG AGT GCG CAG CAC
AGC CAC TTG TTC ATG GTG GA

These primers were annealed, generating 5'
25 overhangs compatible with HindIII on the 5' end and XhoI on the 3' end. The digested vector obtained above, the annealed oligos, and the digested PCR fragment were ligated together and electroporated into DH10B cells. The resulting clone was sequenced to confirm authentic
30 reconstruction of the junction between the signal peptide, OPG binding protein fragment encoding residues 158-316, and the IgG1 Fc domain. The recombinant plasmid was purified, transfected into human 293 fibroblasts, and expressed as a conditioned media product as
35 described above.

Example 11

Peptides of the OPG binding protein and preparation of
5 polyclonal and monoclonal antibodies to the protein

Antibodies to specific regions of the OPG
binding protein may be obtained by immunization with
peptides from OPG binding protein. These peptides may
10 be used alone, or conjugated forms of the peptide may be
used for immunization.

The crystal structure of mature TNF α has been
described [E.Y. Jones, D.I. Stuart, and N.P.C. Walker
(1990) J. Cell Sci. Suppl. 13, 11-18] and the monomer
15 forms an antiparallel β -pleated sheet sandwich with a
jellyroll topology. Ten antiparallel β -strands are
observed in this crystal structure and form a beta
sandwich with one beta sheet consisting of strands
B'BIDG and the other of strands C'CHEF [E.Y. Jones et
20 al., *ibid.*] Two loops of mature TNF α have been
implicated from mutagenesis studies to make contacts
with receptor, these being the loops formed between beta
strand B & B' and the loop between beta strands E & F
[C.R. Goh, C-S. Loh, and A.G. Porter (1991) Protein
25 Engineering 4, 785-791]. The crystal structure of the
complex formed between TNF β and the extracellular domain
of the 55kd TNF receptor (TNF-R55) has been solved and
the receptor-ligand contacts have been described [D.W.
Banner, A. D'Arcy, W. Janes, R. Gentz, H-J. Schoenfeld,
30 C. Broger, H. Loetscher, and W. Lesslauer (1993) Cell
73, 431-445]. In agreement with mutagenesis studies
described above [C.R. Goh et al., *ibid.*] the
corresponding loops BB' and EF of the ligand TNF β were

found to make the majority of contacts with the receptor in the resolved crystal structure of the TNFb:TNF-R55 complex. The amino acid sequence of murine OPG binding protein was compared to the amino acid sequences of TNF α and TNF β . The regions of murine OPG binding protein corresponding to the BB' and EF loops were predicted based on this comparison and peptides have been designed and are described below

A. Antigen(s): Recombinant murine OPG binding protein [158-316] has been used as an antigen (ag) for immunization of animals as described below, and serum will be examined using approaches described below. Peptides to the putative BB' and EF loops of murine OPG binding protein have been synthesized and will be used for immunization; these peptides are:

BB' loop peptide: NH₂--NAASIPSGSHKVTLSSWYHDRGWAKIS--COOH

BB' loop-Cys peptide: NH₂--NAASIPSGSHKVTLSSWYHDRGWAKISC--COOH

EF loop peptide: NH₂--VYVVKTSIKIPSSHNLNLM--COOH

EF loop-Cys peptide: NH₂--VYVVKTSIKIPSSHNLNLMC--COOH

Peptides with a carboxy-terminal cysteine residue have been used for conjugation using approaches described in section B below, and have been used for immunization.

B. Keyhole Limpet Hemocyanin or Bovine Serum Albumin Conjugation: Selected peptides or protein fragments may be conjugated to keyhole limpet hemocyanin (KLH) in order to increase their immunogenicity in animals. Also, bovine serum albumin (BSA) conjugated peptides or protein fragments may be utilized in the EIA protocol. Imject Maleimide Activated KLH or BSA (Pierce Chemical Company, Rockford, IL) is reconstituted in dH₂O to a final concentration of 10 mg/ml. Peptide or protein fragments are dissolved in phosphate buffer then

mixed with an equivalent mass (g/g) of KLH or BSA. The conjugation is allowed to react for 2 hours at room temperature (rt) with gentle stirring. The solution is then passed over a desalting column or dialyzed against
5 PBS overnight. The peptide conjugate is stored at -20°C until used in immunizations or in EIAs.

C. Immunization: Balb/c mice, (Charles Rivers Laboratories, Wilmington, MA) Lou rats, or New Zealand White rabbits will be subcutaneously injected
10 (SQI) with ag (50 µg, 150 µg, and 100 µg respectively) emulsified in Complete Freund's Adjuvant (CFA, 50% vol/vol; Difco Laboratories, Detroit, MI). Rabbits are then boosted two or three times at 2 week intervals with antigen prepared in similar fashion in Incomplete
15 Freund's Adjuvant (ICFA; Difco Laboratories, Detroit, MI). Mice and rats are boosted approximately every 4 weeks. Seven days following the second boost, test bleeds are performed and serum antibody titers determined. When a titer has developed in rabbits,
20 weekly production bleeds of 50 mls are taken for 6 consecutive weeks. Mice and rats are selected for hybridoma production based on serum titer levels; animals with half-maximal titers greater than 5000 are used. Adjustments to this protocol may be applied by
25 one skilled in the art; for example, various types of immunomodulators are now available and may be incorporated into this protocol.

D. Enzyme-linked Immunosorbent Assay (EIA): EIAs will be performed to determine serum antibody (ab)
30 titres of individual animals, and later for the screening of potential hybridomas. Flat bottom, high-binding, 96-well microtitration EIA/RIA plates (Costar Corporation, Cambridge, MA) will be coated with purified recombinant protein or protein fragment (antigen, ag)
35 at 5 µg per ml in carbonate-bicarbonate buffer, pH 9.2

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(0.015 M Na₂CO₃, 0.035 M NaHCO₃). Protein fragments may be conjugated to bovine serum albumin (BSA) if necessary. Fifty µl of ag will be added to each well. Plates will then be covered with acetate film (ICN Biomedicals, Inc., Costa Mesa, CA) and incubated at room temperature (rt) on a rocking platform for 2 hours or over-night at 4°C. Plates will be blocked for 30 minutes at rt with 250 µl per well 5% BSA solution prepared by mixing 1 part BSA diluent/blocking solution concentrate (Kirkegaard and Perry Laboratories, Inc., Gaithersburg, MD) with 1 part deionized water (dH₂O). Blocking solution having been discarded, 50 µl of serum 2-fold dilutions (1:100 through 1: 12,800) or hybridoma tissue culture supernatants will be added to each well. Serum diluent is 1% BSA (10% BSA diluent/blocking solution concentrate diluted 1:10 in Dulbecco's Phosphate Buffered Saline, D-PBS; Gibco BRL, Grand Island, NY)) while hybridoma supernatants are tested undiluted. In the case of hybridoma screening, one well is maintained as a conjugate control, and a second well as a positive ab control. Plates are again incubated at rt, rocking for 1 hour, then washed 4 times using a 1x preparation of wash solution 20x concentrate (Kirkegaard and Perry Laboratories, Inc., Gaithersburg, MD) in dH₂O. Horseradish peroxidase conjugated secondary ab (Boeringer Mannheim Biochemicals, Indianapolis, IN) diluted in 1% BSA is then incubated in each well for 30 minutes. Plates are washed as before, blotted dry, and ABTS peroxidase single component substrate (Kirkegaard and Perry Laboratories, Inc., Gaithersburg, MD) is added. Absorbance is read at 405 nm for each well using a Microplate EL310 reader (Bio-tek Instruments, Inc., Winooski, VT). Half-maximal titre of serum antibody is calculated by plotting the log₁₀ of the serum dilution versus the optical density at 405, then extrapolating at the 50% point of the maximal optical density obtained by

that serum. Hybridomas are selected as positive if optical density scores greater than 5-fold above background. Adjustments to this protocol may be applied; in example, conjugated secondary antibody may
5 be chosen for specificity or non-cross-reactivity.

E. Cell fusion: The animal selected for hybridoma production is intravenously injected with 50 to 100 µg of ag in PBS. Four days later, the animal is sacrificed by carbon dioxide and its spleen collected
10 under sterile conditions into 35 ml Dulbeccos' Modified Eagle's Medium containing 200 U/ml Penicillin G, 200 µg/ml Streptomycin Sulfate, and 4 mM glutamine (2x P/S/G DMEM). The spleen is trimmed of excess fatty tissue, then rinsed through 4 dishes of clean 2x P/S/G DMEM. It
15 is next transferred to a sterile stomacher bag (Tekmar, Cincinnati, OH) containing 10 ml of 2x P/S/G DMEM and disrupted to single cell suspension with the Stomacher Lab Blender 80 (Seward Laboratory UAC House; London, England). As cells are released from the spleen capsule
20 into the media, they are removed from the bag and transferred to a sterile 50 ml conical centrifuge tube (Becton Dickinson and Company, Lincoln Park, NJ). Fresh media is added to the bag and the process is continued until the entire cell content of the spleen is released.
25 These splenocytes are washed 3 times by centrifugation at 225 x g for 10 minutes.

Concurrently, log phase cultures of myeloma cells, Sp2/0-Ag14 or Y3-Ag1.2.3 for mouse or rat splenocyte fusions, respectively, (American Type Culture
30 Collection; Rockville, MD) grown in complete medium (DMEM, 10% inactivated fetal bovine serum, 2 mM glutamine, 0.1 mM non-essential amino acids, 1 mM sodium pyruvate, and 10 mM hepes buffer; Gibco Laboratories, Grand Island, NY) are washed in similar fashion. The
35 splenocytes are combined with the myeloma cells and pelleted once again. The media is aspirated from the

cell pellet and 2 ml of polyethylene glycol 1500 (PEG 1500; Boehringer Mannheim Biochemicals, Indianapolis, IN) is gently mixed into the cells over the course of 1 minute. Thereafter, an equal volume of 2x P/S/G DMEM is slowly added. The cells are allowed to fuse at 37° C for 2 minutes, then an additional 6 ml of 2x P/S/G DMEM is added. The cells are again set at 37°C for 3 minutes. Finally, 35 ml of 2x P/S/G DMEM is added to the cell suspension, and the cells pelleted by centrifugation. Media is aspirated from the pellet and the cells gently resuspended in complete medium. The cells are distributed over 96-well flat-bottom tissue culture plates (Becton Dickinson Labware; Lincoln Park, NJ) by single drops from a 5 ml pipette. Plates are incubated overnight in humidified conditions at 37°C , 5% CO₂. The next day, an equal volume of selection medium is added to each well. Selection consists of 0.1 mM hypoxanthine, 4 x 10⁻⁴ mM aminopterin, and 1.6 x 10⁻² mM thymidine in complete medium. The fusion plates are incubated for 7 days followed by 2 changes of medium during the next 3 days; HAT selection medium is used after each fluid change. Tissue culture supernatants are taken 3 to 4 days after the last fluid change from each hybrid-containing well and tested by EIA for specific antibody reactivity. This protocol has been modified by that in Hudson and Hay, "Practical Immunology, Second Edition", Blackwell Scientific Publications.

While the present invention has been described in terms of the preferred embodiments, it is understood that variations and modifications will occur to those skilled in the art. Therefore, it is intended that the appended claims cover all such equivalent variations which come within the scope of the invention as claimed.

WHAT IS CLAIMED IS:

1. An isolated nucleic acid encoding an osteoprotegerin binding protein selected from the group consisting of:
 - a) the nucleic acid sequence as in Figure 1 (SEQ ID NO:___) and Figure 4 (SEQ ID NO:___);
 - b) nucleic acids which hybridize to the polypeptide coding regions as shown in Figure 1 (SEQ ID NO:___) and Figure 4 (SEQ ID NO:___) and remain hybridized under high stringency conditions; and
 - c) nucleic acids which are degenerate to the nucleic acids of (a) or (b).
2. The nucleic acid of Claim 1 which is cDNA, genomic DNA, synthetic DNA or RNA.
3. A polypeptide encoded by the nucleic acid of Claim 1.
4. The nucleic acid of Claim 1 including one or more codons preferred for Escherichia coli expression.
5. The nucleic acid of Claim 1 having a detectable label attached thereto.
6. A nucleic acid encoding a polypeptide comprising the amino acid sequence of residues 1-316 and residues 70-316 as shown in Figure 1 (SEQ ID NO: ___).
7. A nucleic acid encoding a polypeptide comprising amino acid sequence of residues 1-317 and residues 69-317 as shown in Figure 4 (SEQ ID NO:___);

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8. A nucleic acid encoding a soluble osteoprotegerin binding protein.

9. The nucleic acid of Claim 8 encoding a polypeptide comprising residues 69-317 as shown in Figure 4 (SEQ ID NO:___) and truncations thereof;

10. An expression vector comprising the nucleic acid of Claims 1 and 9.

11. The expression vector of Claim 10 wherein the nucleic acid comprises the polypeptide-encoding region as shown in Figure 1 (SEQ ID NO:___) and Figure 4 (SEQ ID NO:___);

12. A host cell transformed or transfected with the expression vector of Claim 10.

13. The host cell of Claim 12 which is a eucaryotic or procaryotic cell.

14. The host cell of Claim 13 which is Escherichia coli.

15. A process for the production of an osteoprotegerin binding protein comprising:
growing under suitable nutrient conditions host cells transformed or transfected with the nucleic acid of Claim 1; and
isolating the polypeptide product of the expression of the nucleic acid.

16. A polypeptide produced by the process of Claim 15.

17. A purified and isolated osteoprotegerin binding protein, or fragment, analog, or derivative thereof.

5 18. The protein of Claim 17 which is a human osteoprotegerin.

10 19. The protein of Claim 17 having the amino acid sequence as shown in Figure 1 (SEQ ID NO:___) and Figure 4 (SEQ ID NO:___).

20 20. The protein of Claim 17 which has been covalently modified with a water-soluble polymer.

15 21. The protein of Claim 20 wherein the polymer is polyethylene glycol.

20 22. The protein of Claim 17 which is a soluble osteoprotegerin binding protein.

25 23. The protein of Claim 22 comprising the amino acid sequence from residues 70-316 inclusive as shown in Figure 1 (SEQ ID NO: ___), or a fragment, analog, or derivative thereof.

30 24. The protein of Claim 22 comprising the amino acid sequence from residues 69-317 inclusive as shown in Figure 4 (SEQ ID NO:___) and truncations thereof.

35 25. An antibody or fragment thereof which specifically binds an osteoprotegerin binding protein.

 26. The antibody of Claim 25 which is a monoclonal antibody.

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27. A method for detecting the presence of an osteoprotegerin binding protein in a biological sample comprising:

5 incubating the sample with the antibody of Claim 25 under conditions that allow binding of the antibody to the osteoprotegerin binding protein; and
 detecting the bound antibody.

10 28. A method for detecting the presence of osteoprotegerin in a biological sample comprising:

 incubating the sample with an osteoprotegerin binding protein under conditions that allow binding of the protein to osteoprotegerin; and
15 measuring the bound osteoprotegerin binding protein.

 29. A method to assess the ability of a candidate compound to bind to an osteoprotegerin binding protein comprising:

20 incubating the osteoprotegerin binding protein with the candidate compound under conditions that allow binding; and
 measuring the bound compound.

25

 30. The method of Claim 29 wherein the compound is an agonist or an antagonist of an osteoprotegerin binding protein.

30

 31. A method of regulating expression of an osteoprotegerin binding protein in an animal comprising administering to the animal a nucleic acid complementary to the nucleic acids as shown in Figure 1 (SEQ ID NO:___) and Figure 4 (SEQ ID NO: ___).

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36. The method of Claim 35 wherein the modulator is an antibody, or fragment thereof, which specifically binds an osteoprotegerin binding protein.

ABSTRACT OF THE INVENTION

A novel polypeptide, osteoprotegerin binding protein, involved in osteoclast maturation has
5 been identified based upon its affinity for
osteoprotegerin. Nucleic acid sequences encoding the
polypeptide, or a fragment, analog or derivative
thereof, vectors and host cells for production, methods
of preparing osteoprotegerin binding protein, and
10 binding assays are also described. Compositions and
methods for the treatment of bone diseases such as
osteoporosis, bone loss due to arthritis or metastasis,
hypercalcemia, and Paget's disease are also provided.

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FIGURE 1

GAGCTCGGAT CCACTACTCG ACCCACGCGT CCGGCCAGGA CCTCTGTGAA CCGGTCGGGG	60
CGGGGGCCGC CTGGCCGGGA GTCTGCTCGG CCGTGGGTGG CCGAGGAAGG GAGAGAACGA	120
TCGCGGAGCA GGGCGCCCGA ACTCCGGGCG CCGCGCC ATG CGC CGG GCC AGC CGA	175
Met Arg Arg Ala Ser Arg	
1 5	
GAC TAC GGC AAG TAC CTG CGC AGC TCG GAG GAG ATG GGC AGC GGC CCC	223
Asp Tyr Gly Lys Tyr Leu Arg Ser Ser Glu Glu Met Gly Ser Gly Pro	
10 15 20	
GGC GTC CCA CAC GAG GGT CCG CTG CAC CCC GCG CCT TCT GCA CCG GCT	271
Gly Val Pro His Glu Gly Pro Leu His Pro Ala Pro Ser Ala Pro Ala	
25 30 35	
CCG GCG CCG CCA CCC GCC GCC TCC CGC TCC ATG TTC CTG GCC CTC CTG	319
Pro Ala Pro Pro Pro Ala Ala Ser Arg Ser Met Phe Leu Ala Leu Leu	
40 45 50	
GGG CTG GGA CTG GGC CAG GTG GTC TGC AGC ATC GCT CTG TTC CTG TAC	367
Gly Leu Gly Leu Gly Gln Val Val Cys Ser Ile Ala Leu Phe Leu Tyr	
55 60 65 70	
TTT CGA GCG CAG ATG GAT CCT AAC AGA ATA TCA GAA GAC AGC ACT CAC	415
Phe Arg Ala Gln Met Asp Pro Asn Arg Ile Ser Glu Asp Ser Thr His	
75 80 85	
TGC TTT TAT AGA ATC CTG AGA CTC CAT GAA AAC GCA GGT TTG CAG GAC	463
Cys Phe Tyr Arg Ile Leu Arg Leu His Glu Asn Ala Gly Leu Gln Asp	
90 95 100	
TCG ACT CTG GAG AGT GAA GAC ACA CTA CCT GAC TCC TGC AGG AGG ATG	511
Ser Thr Leu Glu Ser Glu Asp Thr Leu Pro Asp Ser Cys Arg Arg Met	
105 110 115	
AAA CAA GCC TTT CAG GGG GCC GTG CAG AAG GAA CTG CAA CAC ATT GTG	559
Lys Gln Ala Phe Gln Gly Ala Val Gln Lys Glu Leu Gln His Ile Val	
120 125 130	
GGG CCA CAG CGC TTC TCA GGA GCT CCA GCT ATG ATG GAA GGC TCA TGG	607
Gly Pro Gln Arg Phe Ser Gly Ala Pro Ala Met Met Glu Gly Ser Trp	
135 140 145 150	
TTG GAT GTG GCC CAG CGA GGC AAG CCT GAG GCC CAG CCA TTT GCA CAC	655
Leu Asp Val Ala Gln Arg Gly Lys Pro Glu Ala Gln Pro Phe Ala His	
155 160 165	
CTC ACC ATC AAT GCT GCC AGC ATC CCA TCG GGT TCC CAT AAA GTC ACT	703
Leu Thr Ile Asn Ala Ala Ser Ile Pro Ser Gly Ser His Lys Val Thr	
170 175 180	

FIGURE 1 (Con't)

CTG TCC TCT TGG TAC CAC GAT CGA GGC TGG GCC AAG ATC TCT AAC ATG	751
Leu Ser Ser Trp Tyr His Asp Arg Gly Trp Ala Lys Ile Ser <u>Asn</u> Met	
185 190 195	
ACG TTA AGC AAC GGA AAA CTA AGG GTT AAC CAA GAT GGC TTC TAT TAC	799
Thr Leu Ser Asn Gly Lys Leu Arg Val Asn Gln Asp Gly Phe Tyr Tyr	
200 205 210	
CTG TAC GCC AAC ATT TGC TTT CGG CAT CAT GAA ACA TCG GGA AGC GTA	847
Leu Tyr Ala Asn Ile Cys Phe Arg His His Glu Thr Ser Gly Ser Val	
215 220 225 230	
CCT ACA GAC TAT CTT CAG CTG ATG GTG TAT GTC GTT AAA ACC AGC ATC	895
Pro Thr Asp Tyr Leu Gln Leu Met Val Tyr Val Val Lys Thr Ser Ile	
235 240 245	
AAA ATC CCA AGT TCT CAT AAC CTG ATG AAA GGA GGG AGC ACG AAA AAC	943
Lys Ile Pro Ser Ser His Asn Leu Met Lys Gly Gly Ser Thr Lys <u>Asn</u>	
250 255 260	
TGG TCG GGC AAT TCT GAA TTC CAC TTT TAT TCC ATA AAT GTT GGG GGA	991
Trp Ser Gly Asn Ser Glu Phe His Phe Tyr Ser Ile Asn Val Gly Gly	
265 270 275	
TTT TTC AAG CTC CGA GCT GGT GAA GAA ATT AGC ATT CAG GTG TCC AAC	1039
Phe Phe Lys Leu Arg Ala Gly Glu Glu Ile Ser Ile Gln Val Ser <u>Asn</u>	
280 285 290	
CCT TCC CTG CTG GAT CCG GAT CAA GAT GCG ACG TAC TTT GGG GCT TTC	1087
Pro Ser Leu Leu Asp Pro Asp Gln Asp Ala Thr Tyr Phe Gly Ala Phe	
295 300 305 310	
AAA GTT CAG GAC ATA GAC T GAGACTCATT TCGTGGAACA TTAGCATGGA	1136
Lys Val Gln Asp Ile Asp	
315	
TGTCCTAGAT GTTTGGA AAC TTCTTAAAA ATGGATGATG TCTATACATG TGTAAGACTA	1196
CTAAGAGACA TGGCCACGG TGTATGAAAC TCACAGCCCT CTCTCTTGAG CCTGTACAGG	1256
TTGTGTATAT GTAAAGTCCA TAGGTGATGT TAGATTCATG GTGATTACAC AACGGTTTTA	1316
CAATTTTGTA ATGATTTTCT AGAATTGAAC CAGATTGGGA GAGGTATTCC GATGCTTATG	1376
AAAACTTAC ACGTGAGCTA TGGAAGGGGG TCACAGTCTC TGGGTCTAAC CCCTGGACAT	1436
GTGCCACTGA GAACCTTGAA ATTAAGAGGA TGCCATGTCA TTGCAAAGAA ATGATAGTGT	1496
GAAGGGTTAA GTTCTTTTGA ATTGTTACAT TGCCTGGGA CCTGCAAATA AGTTCTTTTT	1556

Table 1

Variable	Mean	SD	Range
Age (years)	67.8	9.0	45-85
Gender (% male)	75.0	-	-
Marital status (% married)	75.0	-	-
Educational level (% college graduate)	75.0	-	-
Income (\$1000/monthly)	1.5	0.5	0-3
Health status (% good)	75.0	-	-
Exercise frequency (% weekly)	75.0	-	-
Social support (% strong)	75.0	-	-
Stress level (% low)	75.0	-	-
Mental health score	1.5	0.5	0-3
Physical health score	1.5	0.5	0-3
Quality of life score	1.5	0.5	0-3

[illegible]

Expression of 32D-F3 in COS-7 Cells

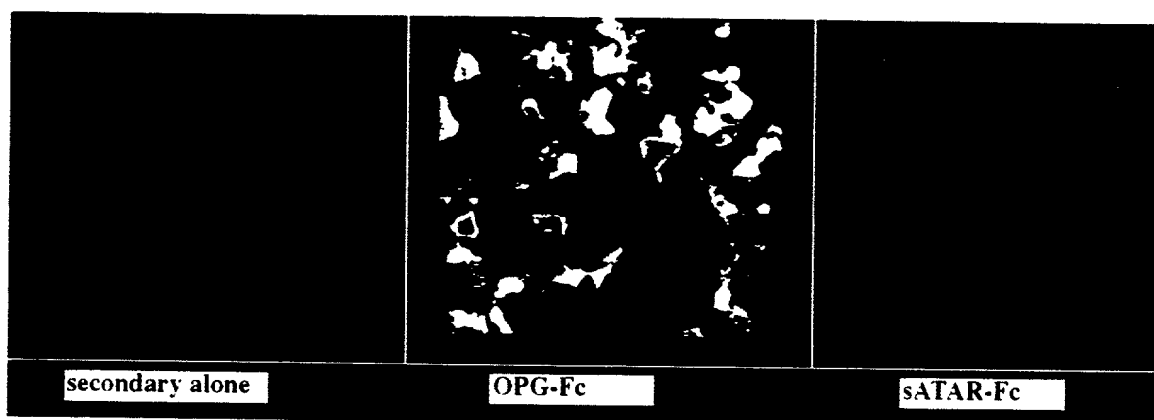


FIGURE 2

OPG Binding Protein Expression in Human Tissues

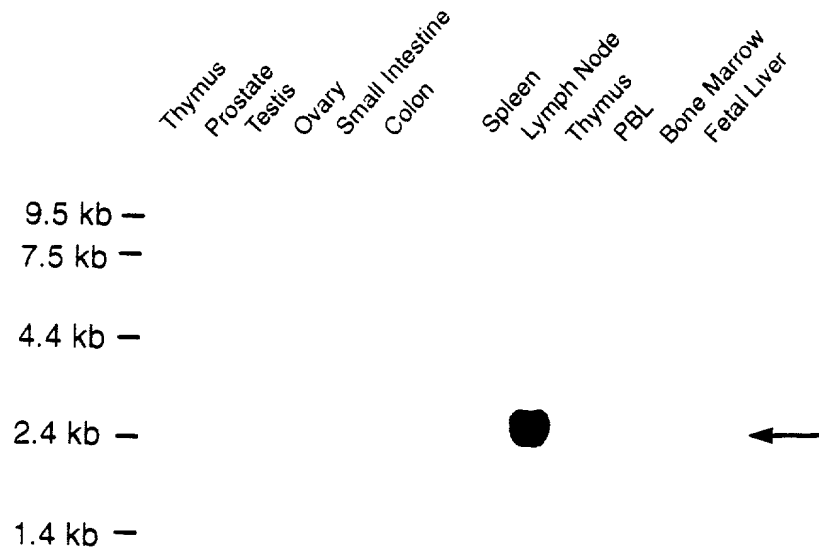


FIGURE 3

FIGURE 4

10 30 50
 AAGCTTGGTACCGAGCTCGGATCCACTACTCGACCCACGCGTCCGCGCGCCCCAGGAGCC
 70 90 110
 AAAGCCGGGCTCCAAGTCGGCGCCCCACGTTCGAGGCTCCGCGCAGCCTCCGGAGTTGGC
 130 150 170
 CGCAGACAAGAAGGGGAGGGAGCGGGAGAGGGAGGAGAGCTCCGAAGCGAGAGGGCCGAG
 190 210 230
 CGCCATGCGCCGCGCCAGCAGAGACTACACCAAGTACCTGCGTGGCTCGGAGGAGATGGG
 M R R A S R D Y T K Y L R G S E E M G
 250 270 290
 CGGCGGCCCCGGAGCCCCGCACGAGGGCCCCCTGCACGCCCCGCGCCCGCCTGCGCCGCA
 G G P G A P H E G P L H A P P P P A P H
 310 330 350
 CCAGCCCCCGCCGCTCCCGCTCCATGTTTCGTGGCCCTCCTGGGGCTGGGGCTGGGCCA
 Q P P A A S R S M F V A L L G L G L G Q
 370 390 410
 GGTTGTCTGCAGCGTCGCCCTGTTCTTCTATTTCAGAGCGCAGATGGATCCTAATAGAAT
 V V C S V A L F F Y F R A Q M D P N R I
 430 450 470
 ATCAGAAGATGGCACTCACTGCATTTATAGAATTTTGAGACTCCATGAAAATGCAGATTT
 S E D G T H C I Y R I L R L H E N A D F
 490 510 530
 TCAAGACACAACCTCTGGAGAGTCAAGATACAAAATTAATACCTGATTCATGTAGGAGAAT
 Q D T T L E S Q D T K L I P D S C R R I
 550 570 590
 TAAACAGGCCTTTCAAGGAGCTGTGCAAAAGGAATTACAACATATCGTTGGATCACAGCA
 K Q A F Q G A V Q K E L Q H I V G S Q H
 610 630 650
 CATCAGAGCAGAGAAAGCGATGGTGGATGGCTCATGGTTAGATCTGGCCAAGAGGAGCAA
 I R A E K A M V D G S W L D L A K R S K
 670 690 710
 GCTTGAAGCTCAGCCTTTTGCTCATCTCACTATTAATGCCACCGACATCCCATCTGGTTC
 L E A Q P F A H L T I N A T D I P S G S
 730 750 770
 CCATAAAGTGAGTCTGTCTCTTGGTACCATGATCGGGGTGGGCCAAGATCTCCAACAT
 H K V S L S S W Y H D R G W A K I S N M
 790 810 830
 GACTTTTAGCAATGGAAACTAATAGTTAATCAGGATGGCTTTTATTACCTGTATGCCAA
 T F S N G K L I V N Q D G F Y Y L Y A N
 850 870 890
 CATTTGCTTTTCGACATCATGAACTTCAGGAGACCTAGCTACAGAGTATCTTCAACTAAT
 I C F R H H E T S G D L A T E Y L Q L M
 910 930 950
 GGTGTACGTCACTAAAACCAGCATCAAAATCCCAAGTTCTCATACCCTGTAGAAAGGAGG
 V Y V T K T S I K I P S S H T L M K G G
 970 990 1010

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FIGURE 4

AAGCACCAAGTATTGGTCAGGGAATTCTGAATTCCATTTTTATTCCATAAACGTTGGTGG
S T K Y W S G N S E F H F Y S I N V G G

1030 1050 1070
ATTTTTTAAGTTACGGTCTGGAGAGGAAATCAGCATCGAGGTCTCCAACCCCTCCTTACT
F F K L R S G E E I S I E V S N P S L L

1090 1110 1130
GGATCCGGATCAGGATGCAACATACTTTGGGGCTTTTAAAGTTCGAGATATAGATTGAGC
D P D Q D A T Y F G A F K V R D I D

1150 1170 1190
CCCAGTTTTTGGAGTGTTATGTATTTCTGGATGTTTGGAAACATTTTTTAAAAACAAGCC

1210 1230 1250
AAGAAAGATGTATATAGGTGTGTGAGACTACTAAGAGGCATGGCCCCAACGGTACACGAC

1270 1290 1310
TCAGTATCCATGCTCTTGACCTTGTAGAGAACACGCGTATTTACAGCCAGTGGGAGATGT

1330 1350 1370
TAGACTCATGGTGTGTACACAATGGTTTTTAAATTTTGTAAATGAATTCCTAGAATTAAA

1390 1410 1430
CCAGATTGGAGCAATTACGGGTGACCTTATGAGAACTGCATGTGGGCTATGGGAGGGG

1450 1470 1490
TTGGTCCCTGGTCATGTGCCCCCTTCGCAGCTGAAGTGGAGAGGGTGTCATCTAGCGCAAT

1510 1530 1550
TGAAGGATCATCTGAAGGGGCAAATTCCTTTGAATTGTTACATCATGCTGGAACCTGCAA

1570 1590 1610
AAAATACTTTTTCTAATGAGGAGAGAAAATATATGTATTTTTATATAATATCTAAAGTTA

1630 1650 1670
TATTTTCAGATGTAATGTTTTCTTTGCAAAGTATTGTAAATTATATTTGTGCTATAGTATT

1690 1710 1730
TGATTCAAAATATTTAAAAATGTCCTTGCTGTTGACATATTTAATGTTTTAAATGTACAGA

1750 1770 1790
CATATTTAACTGGTGCACTTTGTAAATTCCTGGGGAAAACTTGCAGCTAAGGAGGGGAA

FIGURE 4

1810 1830 1850
AAAAATGTTGTTTCCTAATATCAAATGCAGTATATTTCTTCGTTCTTTTAAAGTTAATAG
1870 1890 1910
ATTTTTTCAGACTTGTCAAGCCTGTGCAAAAAAATTAAAAATGGATGCCTTGAATAATAAG
1930 1950 1970
CAGGATGTTGGCCACCAGGTGCCTTTCAAATTTAGAACTAATTGACTTTAGAAAGCTGA
1990 2010 2030
CATTGCCAAAAAGGATACATAATGGGCCACTGAAATCTGTCAAGAGTAGTTATATAATTG
2050 2070 2090
TTGAACAGGTGTTTTTCCACAAGTGCCGCAAATTGTACCTTTTTTTTTTTTTTCAAATAG
2110 2130 2150
AAAAGTTATTAGTGGTTTATCAGCAAAAAAGTCCAATTTTAATTTAGTAAATGTTATCTT
2170 2190 2210
ATACTGTACAATAAAAACATTGCCTTTGAATGTTAATTTTTTGGTACAAAAATAAATTTA
2230 2250 2270
TATGAAAAAAAAAAAAAGGGCGGCCGCTCTAGAGGGCCCTATTCTATAG

Sequence alignment

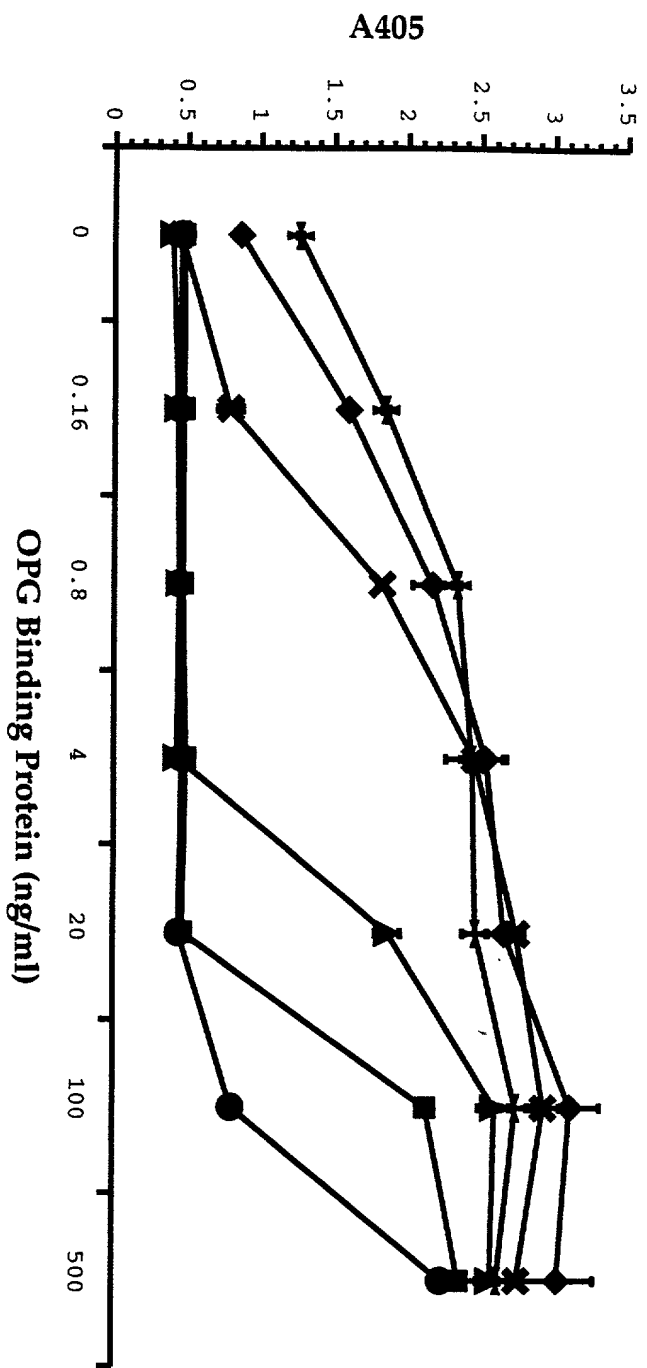


FIGURE 5

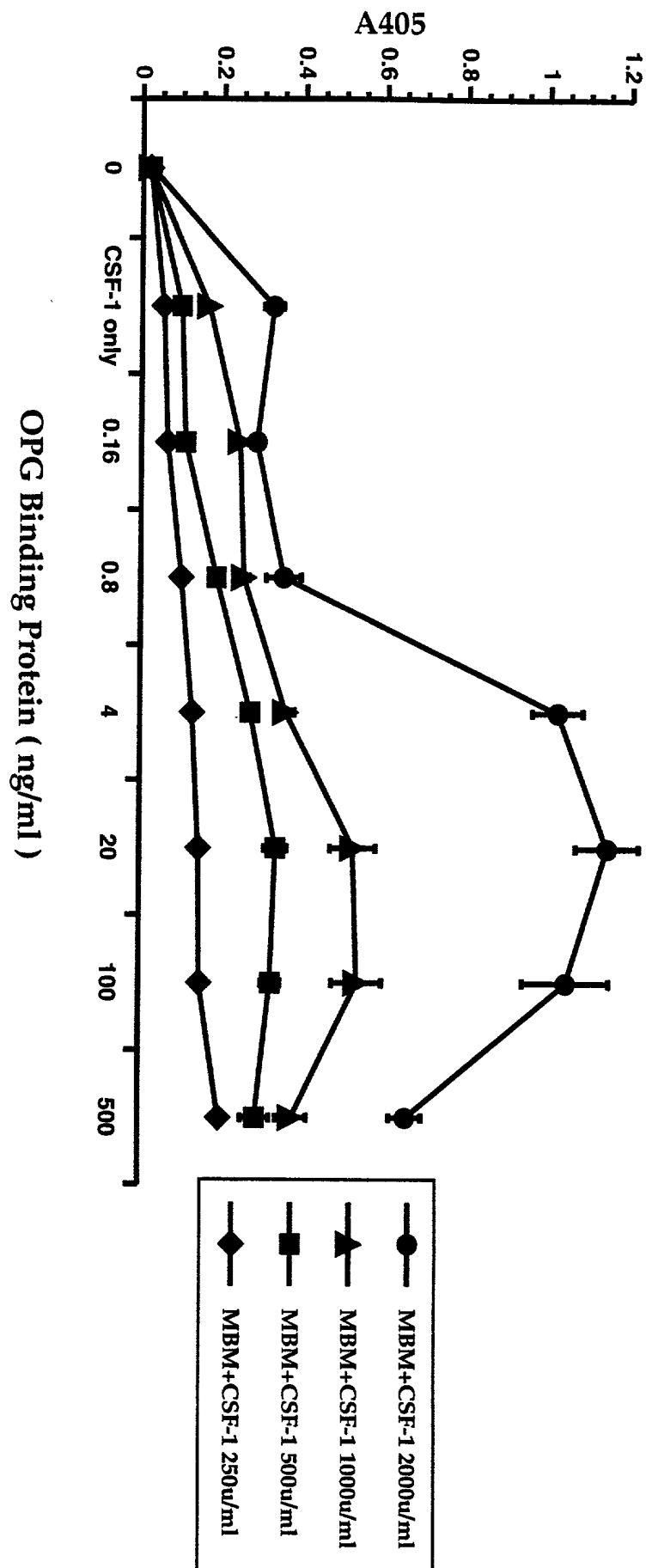
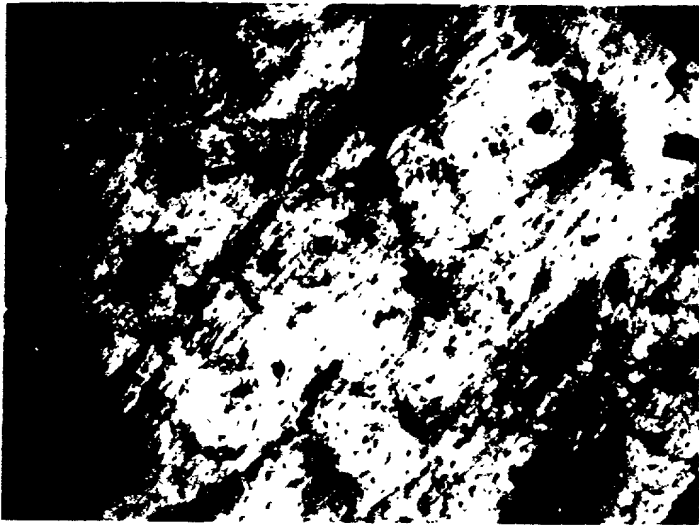
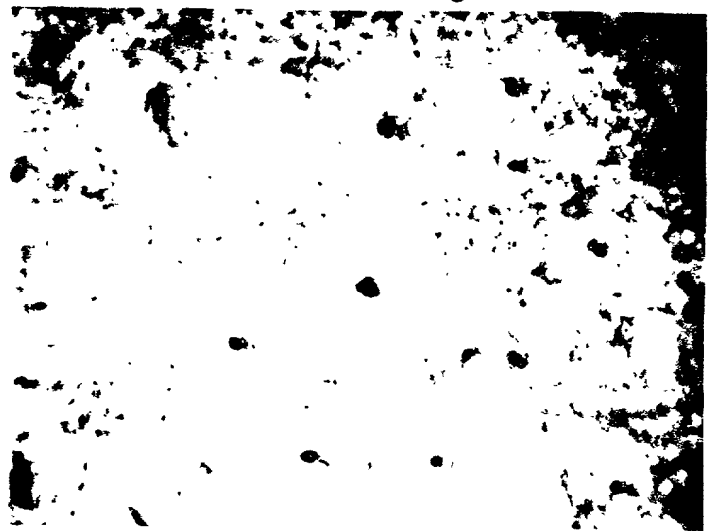


FIGURE 6

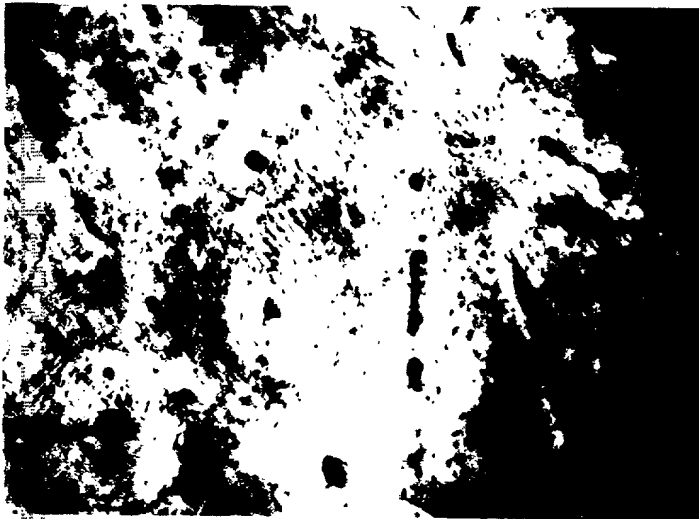
Toluidine Blue Staining



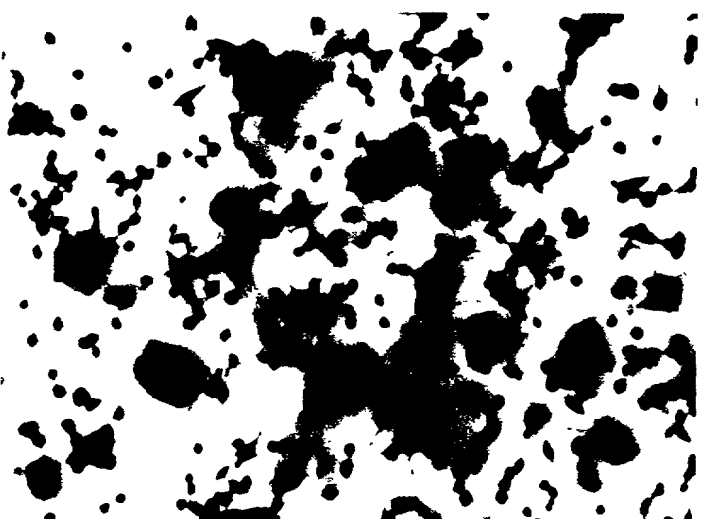
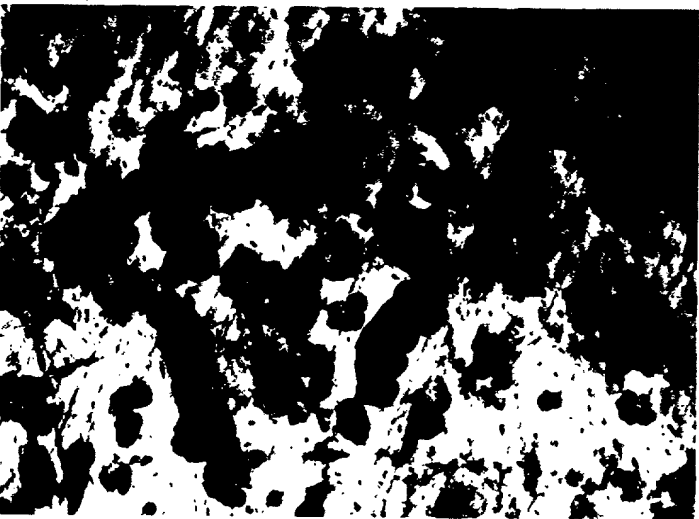
TRAP staining



Bone Marrow Cells + M-CSF-1



Bone Marrow Cells + OPG Binding Protein



Bone Marrow Cells + M-CSF-1 + OPG Binding Protein

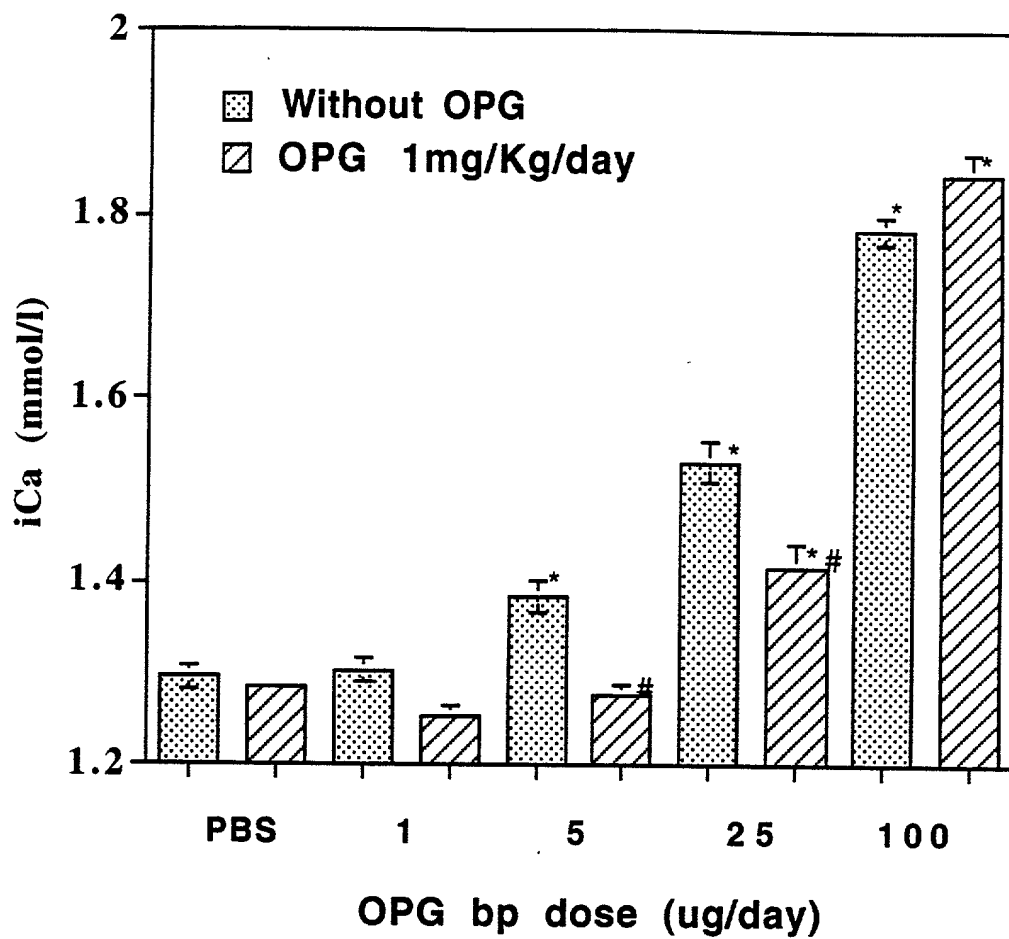


FIGURE 8

0921397-131498
SECRET 2627250

PBS



OPGbp 5ug/d



OPGbp 25ug/d



OPGbp100ug/d



FIGURE 9

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or a joint inventor (if plural names are listed below) of the invention entitled

OSTEOPROTEGERIN BINDING PROTEINS

which is described and claimed in the specification which:

- ☒ is attached hereto.
☐ was filed on _____
as Application Serial No. _____
and was amended on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the filing date of this application:

APPLICATION SERIAL NO.	FILING DATE	STATUS
08/842,842	April 16, 1997	Pending

Power of Attorney: As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

Ron K. Levy, Registration No.: 31,539; Steven M. Odre, Registration No.: 29,094; and Robert B. Winter, Registration No.: 34,458 said attorneys/agents to have in addition full power of revocation, including the power to revoke any power herein granted.

EXPRESS MAIL CERTIFICATE

"Express Mail" mail labeling number: TB813684146

Date of Deposit: June 23, 1997

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to Bell Patent Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

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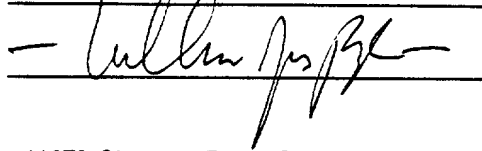
Robert B. Winter
 Attorney/Agent for Applicant(s)
 Registration No.: 34,458
 Phone: (805) 447- 2425
 Date: June 23, 1997

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Full Name of Sole
 or First Inventor:

WILLIAM J. BOYLE

Inventor's Signature:



Date:

6.23.97

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